THE JOURNAL

OF

"The Royal Aeronautical Society"

with which is incorporated "The Institution of Aeronautical Engineers"

Edited for the Council by Captain J. LAURENCE PRITCHARD, Hon. Fellow

No. 214. OCTOBER, 1928. Vol. XXXII.

NOTICES

R.38 Memorial Prize

Members are reminded that the R.38 Memorial Prize entries must be received by December 31st. The closing date for papers is March 31st. The R.38 Memorial Prize is offered annually for the best paper received by the Society on some subject of a technical nature in the science of aeronautics, preference being given to papers which relate to airships. The prize is twenty-five guineas.

R.38 Memorial Prize Award

The R.38 Memorial Prize for 1927 has been awarded by the Council, as a result of the report of the referees, to Mr. H. Roxbee Cox for his paper on "The External Forces on an Airship Structure with Special Reference to the Requirements of Rigid Airship Design." The paper, which is a very lengthy and important one, will be published in a forthcoming issue of the Journal.

The Sir Charles Wakefield Gold Medal

The Sir Charles Wakefield Gold Medal, awarded annually to the designer of any invention or apparatus tending towards safety in flying, has been awarded by the Council to Mr. F. Handley Page for his work in connection with the automatic slot.

The Society's Silver Medal

The Silver Medal of the Society, which is awarded for some advance in aeronautical design, has been awarded for the year 1927-28 to Mr. B. N. Wallis for his work in connection with the design of airships.

Income Tax

The following letter has been received from the Income Tax Commissioners:—

Somerset House,
14th August, 1928.

Dear Sir,

Further to your interview with Mr. Stanley at this office on the 19th July, I am now in a position to inform you that the Board of Inland Revenue will not raise objection to the allowance as an expense for Income Tax purposes of annual subscriptions paid by members who are—

(I.) Assessable under Schedule D of the Income Tax Acts in respect of professional or trading profits, subject to the decision of the Commissioners who make the assessment that such subscriptions are sufficiently closely related to the business carried on, or

(II.) Assessable under Schedule E in those cases only in which continued membership of the Society is an essential condition of the terms of appointment.

Yours faithfully,
(Signed) GEO. WILCOCK,
Principal Inspector of Taxes.

Capt. J. L. Pritchard, *Secretary*,
Royal Aeronautical Society.

Council Meeting

A Meeting of Council was held on Tuesday, September 11th. Among the business transacted was the awards of the Sir Charles Wakefield Gold Medal, the Silver Medal and the R.38 Memorial Prize; elections on the report of the Grading Committee; the consideration of the half-yearly accounts; the report of the Finance Committee; the Lecture Programme for the second half of the 1928-29 Session; and the Exhibit of the Society at the Berlin Exhibition in October.

There were present at the Council Meeting:—

Colonel the Master of Sempill (*President*) in the chair.

Sir Sefton Brancker (*Past President*).
Mr. Griffith Brewer.
Wing Cdr. T. R. Cave-Browne-Cave.
Mr. F. T. Hill.
Mr. J. E. Hodgson (*Hon. Librarian*).
Major D. H. Kennedy (*Hon. Treasurer*).
Captain A. G. Lamplugh.
Mr. W. O. Manning.
Mr. F. Handley Page.
Sir Vyell Vyvyan (*Vice-President*).
Mr. L. A. Wingfield.
Mr. R. McKinnon Wood.

Finance Committee

A meeting of the Finance Committee was held on 10th September, 1928. Present:—Major D. H. Kennedy (Hon. Treasurer) in the chair, Mr. J. E. Hodgson, Mr. A. N. D. Smith (Hon. Accountant) and Mr. L. A. Wingfield.

Grading Committee

A meeting of the Grading Committee was held on September 11th, 1928. Present:—Wing Commander T. R. Cave-Browne-Cave (in the chair), Major P. Bishop, Mr. F. T. Hill, Captain A. G. Lamplugh, Mr. R. K. Pierson, Mr. W. P. Savage and Colonel the Master of Sempill.

Technical Information Index

A card index of information has been formed at the Society's offices, giving references to articles, papers and books on all aspects of the science of aeronautics and its allied sciences. The index, which is being added to every week, already contains some 10,000 references, and it is hoped, in time, to make it one of the biggest aeronautical indexes extant. The use of this index is free to all members of the Society, and those who wish, at any time, to obtain information on any particular branch of aeronautics will receive such references as are available on application to the Secretary. A list of publications covered by the index was published in the April Journal. This list has since been considerably enlarged.

Library

The following have been received and placed in the Library:—

Scientific Papers of the Ins. of Physical and Chemical Research, Tokyo—

No. 139. The Photogalvanic Cell Furnished with Silver Iodide Electrodes, and its Application to Photometry and Illuminometry. S. Ilmori and T. Takebe.

No. 140. Uber die Stereoisomerie des 8-Oxydekahydrochinolins und Seiner Derivate. S. Fujise.

No. 141. Quantitative Determination of Hæmoglobin by means of the Silver Iodide Photogalvanic Cell. K. Uchiyama.

No. 142. Untersuchung der Dekhydrochinolinderivate III. Mitteilung. Uber den Hofmannschein abbau des Dekahydrochinolins. S. Fujise.

No. 143. Experimental Studies on Form and Structure of Sparks, Part IV. T. Terada, U. Nakaya and R. Yamamoto.

No. 144. Interferential Collimator and Prisms. H. Nagaoka and T. Mishima.

Nos. 145-155.

Abstracts from the Bulletin of the Institute of Physical and Chemical Research, Tokyo, Vol. VII.—

No. 4. (In English.)
No. 5. (In English.)
No. 6. (In English.)

Supplement to Scientific Papers of the Institute of Physical and Chemical Research, Tokyo, Vol. VIII.—

Nos. 2-3.
Nos. 4-5.

Report of the Aeronaut. Research Institute, Tokyo. No. 38, On Gustiness of Winds. T. Terada.

Abstracts from the Technical Press appertaining to Performance of Aircraft and Engines.

Abstracts and Notices from the Scientific and Technical Press.

The Bureau of Information on Nickel, Ltd., Series B, Paper No. 3, Advantages, Application and Technology of Nickel Cast Iron.

Aeronautical Research Committee, Report for the Year 1927-28.

R. & M. No. 1117. Scale Effect on Three Aerofoils at Low Values of LV, R.A.F. 32, Göttingen 433 and Göttingen 410 with 2 per cent. Centre Line Camber. F. B. Bradfield.

R. & M. No. 1121. The Experimental Determination of the Trajectory of Aircraft Bombs. H. E. Wimperis.

R. & M. No. 1127. Further Development of Autogyro Theory, Parts I. and II. C. N. H. Lock.

R. & M. No. 1138. The Determination of the Elastic Moduli of a Mild and a Medium Steel. H. E. Smith and H. L. Cox.

R. & M. No. 1144. Report on the Development of a Hot-Wire Rate of Descent Meter. G. W. H. Gardner and F. W. Meredith.

R. & M. No. 1149. Variable Density Wind Tunnel. Scale Effect Panel.

R. & M. No. 1157. On the Horizontal Flight of a Helicopter. H. Glauert.

R. & M. No. 1160. The Resistance of the International Airship Models Measured in the Wind Tunnel of the Royal College of Science, South Kensington, S.W.7. F. T. Hill and T. Tanner.

A.P. 1234. Manual of Air Pilotage.

Air Ministry Publications—
No. 5. Resumé of Commercial Information, Series 4, Dec. 27—April, 1928. D. C. A.
No. 6. May—June, 1928.
No. 1082. 3rd Edtn. May, 1928. Jaguar Series III.A Aero Engine.

Air Force Act.

Geophysical Memoirs—
M.O. 307a, No. 41. The Influence of Arctic Ice. C. E. P. Brooks and W. A. Quennell.

Department of Scientific and Industrial Research, Engineering Research, Special Report No. 9, Researches on Springs, 3—Torsional Fatigue Tests on Spring Steels. G. A. Hankins.

Amendment List No. 2 to A.P. 1208—
Airworthiness Handbook for Civil Aircraft.

Aerobatics. O. Stewart.

Gentlemen Prefer Aeroplanes. E. F. Spanner.

Engineering Aerodynamics. W. S. Diehl.

Elements of Aviation. V. E. Clark.

Memoirs of the Royal Meteorological Society, Vol. II.—
No. 20. Eddy-Viscosity and Skin Friction in the Dynamics of Winds and Ocean Currents. V. A. Ekman.
Vol. III., No. 21. Further Studies in Terrestrial Radiation. G. C. Simpson.

Dominion of Canada. Department of National Defence. Report on Civil Aviation and Civil Government Air Operations for the year, 1927.

Institution of Engineers and Shipbuilders in Scotland. The Uses of Nickel Deposits for Engineering Purposes. C. H. Faris. (Reprint.)

Bulletin du Service Technique de l'Aéronautique—
No. 6. Accélérographe F. Bouny pour la Mesure de l'Acceleration des Avions en Vol. F. Bouny.
No. 7. Résultats d'essais Aérodynamiques. P. Puvrez.

Luftflotten. LIX. Year.

Luftfahrtforschung, Berichte der DVL, AVA, AIA, 2 Band, S.1-32, Heft 1, Uber Profilwiderstandsmessung im Fluge nach dem Impulsverfahren. M. Schrenk.

Mitglieder-Verzeichnis, des Vereines Deutscher Ingenieure.

Deutsche Kraftfahrzeug-Typenschau, Ausgabe I.: Luftfahrzeuge und Luftfahrzeugmotoren.

Journal of the Institute of Metals, No. I., 1928, Vol. XXXIX.

Transactions of the Institution of Engineers and Shipbuilders in Scotland, Vol. LXX., 1926-7.

Transactions of the Chartered Institute of Patent Agents, Vol. XLVI., 1927-8.

Transactions of the Institute of Marine Engineers, Vol. XXXIX., 1927.

Empire Forestry Journal, Vol. VII., No. 1.

Charter Centenary Celebration, 3rd to 7th June, 1928. Institution of Civil Engineers.

List of Members. Institution of Civil Engineers.

Industrial Arts Index, 1928.

Poutre Uniformement Chargé avec une partie en porte. A. Van der Vliet.

Andalucia Aeronautics, No. 1, Vol. I. (Journal of the Royal Aero Club of Andalusia.)

Forthcoming Arrangements

Thursday, October 4th, 6.30 p.m.—Inaugural Lecture. Mr. J. D. North, F.R.Ae.S., M.I.Ae.E., "The Technical Development of the Aeroplane," at the Royal Society of Arts, 18, John Street, Adelphi, W.C.2.

Tuesday, October 16th, LEEDS BRANCH.—Professor S. Brodetsky, F.R.Ae.S., "The Aerodynamics of Wing Sections."

Thursday, October 18th, 6.30 p.m.—Mr. H. Sutton, M.Sc., "Light Alloys and their Use in Aircraft," at the Royal Society of Arts, 18, John Street, Adelphi.

Monday, October 22nd, YEOVIL BRANCH.—Brigadier-General P. R. C. Groves, C.B., C.M.G., D.S.O., "Britain's Position in World Aviation."

J. LAURENCE PRITCHARD, *Secretary.*

PROCEEDINGS

SIXTH MEETING, SECOND HALF, 63RD SESSION

A meeting of the Royal Aeronautical Society was held in the rooms of the Royal Society of Arts, John Street, Adelphi, London, W.C.2, on Thursday, March 15th, 1928, Colonel the Master of Sempill (President of the Society) in the chair.

The CHAIRMAN said that this was the first meeting of the Society since an unusual number of fatal accidents had occurred. Perhaps the greatest loss was that of Flight Lieutenant Kinkead, when attempting to capture the world's speed record in the Supermarine Napier S5. He was unquestionably one of the finest pilots in a Service renowned throughout the world for its magnificent pilots, and the members of the Society would wish to pay a special tribute to his memory and to the memory of two others we had recently lost. He asked those present to stand in silence for a few minutes.

THE EQUIPMENT OF FLYING BOATS

The CHAIRMAN, in calling upon Flight Lieutenant B. C. H. Cross, D.F.C., to read a paper on this subject, said that he was one of the first to join the Royal Naval Air Service at the beginning of the War, and had a unique record, because at the end of 1915 or the beginning of 1916 he had become associated with seaplanes and flying boats, and for the last twelve years he had been occupied exclusively with the operation and development of these craft. His knowledge on the equipment of flying boats was unequalled. He had taken part in the first cruise of flying boats to the Scilly Isles, under Wing Commander Maycock; in the Mediterranean cruise of the "Southamptons"; and in the Baltic cruise in 1927, in all of which he had played a prominent part, and no doubt their successful issue had been due to a large extent to his skill and initiative.

Prior to the reading of the paper short cinematograph films were exhibited, depicting the "Iris II." leaving for the Baltic cruise; the construction and launching of the "Calcutta"—the largest commercial all-metal flying boat in the world; the first flight of the "Calcutta"; and the departure of the "Singapore" for Africa.

BY FLIGHT LIEUTENANT B. C. H. CROSS.

Perhaps nothing reveals the weakness of a flying boat and its equipment with more rapidity and certainty than a cruise which involves a prolonged absence from organised bases.

Relatively few have had this unique experience, and unhappily no designers of air craft in this country. Words alone cannot conjure up the atmosphere, the petty anxieties, the continual working against time, the struggle in rain and rolling swells, the idiosyncrasies of motor boats, the enthusiasm of crews snatching food when they can get it, and a thousand ills that flying boats are heir to. But it is an exhilarating life that takes a firm hold of all that fall beneath its influence.

In their eternal struggle for lightness, designers must often look askance at points outlined by pilots, for the peaceful office is not conducive to a realisation of practical difficulties.

It is the object of this paper to suggest the requirements of flying boat equipment based particularly on the experience of the past six years. At times it must appear that obvious detail has been emphasised; let me hasten to assure you that usually the obvious has suffered the most neglect.

Mooring Equipment

On the mooring equipment depends the safety of the flying boat on the water, and its design deserves the fullest consideration.

Mooring Fittings, Past and Present

In the earliest types of flying boats, including the F.5 series, the idea of mooring had hardly been considered, and we find that all fittings were designed for towing purposes. The main fitting was on the keel, well forward, and a wire was shackled to this point and led directly to the towing craft. This wire was limited in its lateral and downward movement by a short wire through the eye of which it passed, attached to a fitting in the bows of the boat.

A flying boat towed in this manner yawed very considerably, more particularly in a side wind and swell. To overcome this and to reduce the strain on the hull fitting, which occasionally was wrenched completely out of the hull, the "Yarmouth" gear was introduced. This consisted essentially of wires led from each of the engine-bearer struts and meeting forward, where they were shackled to the towing line.

When the first experiments in mooring out were commenced, the towing system was used for this purpose, and indeed has continued to this day, almost without change in its essentials.

Towing and mooring are however two entirely distinct operations, the forces acting on the flying boat being in different directions. In towing, particularly at sea, the tow line is either horizontal to the surface or during the process of towing at speed actually inclined upwards from the flying boat to the surface craft. The length of tow is adjusted so that a moment is set up assisting the hull to ride at the correct attitude for planing on its step, and the wings are at a considerable angle of incidence.

In mooring, the cable to the sinker is invariably inclined downwards from the flying boat, and when the attachment is near the bows a downward moment occurs which tends to hold the bows into the sea and to decrease the angle of incidence of the wings. In a swell, the incidence is constantly changing, and may be as much as 10 degrees more than normal.

It is suggested that the introduction of the downward moment in the bows causes the hull to be more unstable longitudinally than an attachment of the cable to a position nearer the centre of buoyancy. This is accentuated in practice by the limitations imposed by moorings, but it also has an important bearing on the problem of anchoring. By attaching the anchor line to the point of minimum movement on the hull, the variation in the loads imposed upon the anchor will obviously be reduced to a minimum.

Limiting Factors of Moorings

Congested harbours, estuaries, sites on the edge of fairways and obstacles frequently necessitate a small swinging circle for the moored flying boat. The relatively short mooring cable to sinkers is liable to be at a comparatively steep angle at high water, and in strong winds the vertical component of the drag is liable to become considerable.

A case recently occurred in which a flying boat moored to a two-ton sinker, dragged the latter 140 feet. The angle which the mooring cable made to the bottom at low tide was approximately 25 degrees, and the wind reached in gusts 70 miles an hour. It was observed that with each swell that passed, the bows nosed into the sea and the flying boat appeared to surge forward.

The Effect of Deep Hulls

As the displacement of flying boats grows, and the Vee-bottom is accentuated, causing increased draught, the effect of tide becomes more noticeable. In light winds up to about 15 miles per hour, a two-knot tide is sufficient to cause the flying boat to ride to tide rather than to wind. At winds approaching 20 miles per hour, the flying boat faces the wind. During the intermediate stage, the resultant of tide and wind causes the flying boat to ride with the mooring wire at about right angles to the hull.

The length of the mooring wire is consequently limited to a distance slightly less than the span from the hull to the wing-tip float, otherwise damage to the latter on a buoy is liable to result.

This lateral strain on the hull fittings, which might be considerable in a swell, should not be overlooked.

The Design of Mooring Fittings

It is suggested that the main hull fitting should be on the keel a shorter distance ahead of the centre of buoyancy than at present, and that the mooring wire should pass through a restraining wire from the bows, of such a length that free vertical movement of the mooring wire through a wide range is permitted, but its horizontal movement is confined to angles well ahead of the beam.

The mooring and restraining wires should be spliced round thimbles and shackled to fittings to ensure ease in replacement. Insistence on such obvious details may at first sight appear superfluous. I will merely content myself with the remark that they receive scant consideration from some designers.

The mooring wire should have a factor of safety of at least ten, as it is liable to spend months on end mainly below water and is liable to chafing.

It is not unlikely that the advent of an entirely reliable mooring gear from the hull will enable the "Yarmouth" gear to be dispensed with, indeed the present "Far East Flight" are relying on improvising the gear when necessary. It may be of interest to mention that the continual rattling of the wire on the hull is a matter of great discomfort when attempting to sleep aboard.

The Provision of an Anchor

The natural result of the flying boat's development in range and seaworthiness has been to bring into prominence the question of equipping it so that it can be independent of organised shore bases. Among the problems to be solved, that of carrying an anchor to avoid the necessity of having special moorings laid, has been emphasised, indeed not infrequently exaggerated by a number of uninformed writers.

The investigation as to the possibility of anchoring a flying boat, naturally divided itself into two channels:—

(*a*) Ascertaining the drag of a flying boat at anchor.
(*b*) Examining the factors affecting the holding powers of an anchor, with a view to designing the most efficient type for the limited weight allowed.

Effect of Wind and Tide

Two forces act upon the moored flying boat, namely, wind and tide.

Full-scale experiment has shown that the force due to the wind varies with the attitude of the flying boat to the swell.

The wind exerts a force which approximates to the drag coefficient of the flying boat, and experience shows that allowance for angles of pitch some 10 degrees greater than normal have to be made owing to the swell.

It will be appreciated that an F.5 is an old design, but at the time in question it happened to be the only aircraft available to carry out this experiment. Since the main planes of an F.5 are at six degrees to the horizontal, the drag is necessarily higher than in more modern types of similar dimensions.

The experiment showed clearly that in anchoring it is of greater importance to obtain shelter from the swell than from the wind.

In this connection it will be obvious that the movement of any part of the hull increases in proportion to its distance from the centre of buoyancy. Hence the attachment of the anchor line to the mooring wire, fitted as already suggested in this paper, will tend to avoid extreme loads on the line.

The force due to the tide is of lesser importance, but has been shown to approximate roughly to:—

$$R = 1.2LV^3/10{,}000$$

Where R = drag due to the tide in lbs.
L = displacement in lbs.
V = tide speed in knots.

The Limitations Imposed on Anchor Design

An example of the magnitude of the problem may be quoted.

A flying boat having a displacement of 20,000 lbs. is required to be fitted with an anchor, which complete with anchor line is to be limited in weight to 75 lbs.

For a launch having approximately the same length of water line, Lloyds require an anchor weighing 120 lbs. in addition to chain cable, which may weigh an extra 250 lbs.

In a wind of 30 miles per hour the flying boat may be expected to have a drag of 570 lbs.; in a 40 mile per hour wind, the drag has risen to 1010 lbs. If there is a tide running of 5 knots, there will be an additional drag of approximately 300 lbs.

It is unlikely that the drag of the launch under similar circumstances of wind and tide will exceed 700 lbs.

Nevertheless, in this example, the launch has five times the weight of anchor equipment allowed for the flying boat, to hold half the drag.

Anchor Research

Since anchors have been in use in ships for countless centuries, it might have been anticipated that anchor design would have been a comprehensive and exact science. Exhaustive recent inquiries, which included in their scope the Institution of Naval Architects and the library of the British Museum, resulted only in a reference to the Encyclopedia Britannica; information from "Lloyds" was to the effect that tables of weights of anchors and cable sizes were solely based on practice. Since all data available were of a similar unscientific nature, it was soon apparent that the problem of anchoring flying boats would have to be tackled from first principles.

In the first place anchors of suitable size and weight had to be procured in order to ascertain whether any existing anchors fulfilled requirements, or gave promise of successful development.

The trials were carried out on a foreshore composed of mixed sand and shingle. The apparatus consisted of a staging which supported a pulley over which ran the line led from the anchor. The line was loaded up and the weight required to drag the anchor ascertained. The dragging was repeated several times at varying lengths of measured line. Some of the results obtained are tabulated:—

TABLE 1.

Anchor.	Weight in lbs.	Holding Factor.	Remarks.
A. With stock	20	5·5	Fitted with very broad flukes having blunt ends.
B. ,, ,,	30	4·3	Almost exactly like A, but to larger scale.
C. ,, ,,	7	13.6	Anchor supplied for use with Short 184 type float seaplanes.
D. ,, ,,	23	4.6	Similar in shape to A, but with smaller flukes and less weight concentrated on the crown.
E. ,, ,,	50	4.0	Anchor characterised by large pointed flukes and with almost flat crown. Most of the weight appeared to be in the shank.
F. ,, ,,	47	6.4	Anchor with broad sharp flukes and a heavy crown in the form of a large arc. Tested in practice and held well in moderate weather.

The "holding factor" is a term coined to denote the ratio of the holding power (*i.e.*, pull at which the anchor drags) to the weight of anchor.

From this preliminary survey it was obvious that unless considerable advance could be made, the provision of an anchor was hardly justified.

The result of a lengthy examination of the problem is shown in Table 2.

TABLE 2.

Anchor.	Weight in lbs.	Holding Factor.	Remarks.
Felixstowe Mark 9	70	8.6	Similar to E, but with large triangular flukes and with shank lengthened to 5ft. 3in.
Felixstowe Mark 10	60	10.4	Mark 9 with shank lightened by grooving to H section.
Felixstowe Mark 11	63	11.1	Mark 10 with stock reduced 4in. in length and crown made detachable. This anchor was highly successful, but below strength in the fluke supports and shank near crown.
Felixstowe Mark 12	62	11.3	Mark 11 redesigned to have a better strength distribution. In practice, this anchor held fluctuating loads up to 1,000 lbs. The detachable crown and folding stock make stowage a simple problem.

The Felixstowe Mark 12 anchor, it will be noted, will hold up to 700 lbs. for a weight of 62 lbs. as compared with a pull of 300 lbs. for 47 lbs. being the best commercial anchor tested. This anchor was used successfully throughout the Baltic cruise and is being carried by the Far East Flight, and may be expected to hold a boat of the size of the "Southampton" in winds up to 30 miles per hour in a moderate swell, with a small factor of safety.

It may be safely stated that even if hitherto no anchor has yet been evolved that for a moderate weight, which will safely hold a flying boat in all conditions

likely to be met, the better type of anchor has a very considerable degree of usefulness already, and that the whole problem is worthy of systematic inquiry. This is now being carried out with an anchor which can be varied in its dimensions and shape.

Loading the Anchor Line

The use of chain cable on anchors is standard practice with marine craft and it is generally claimed that this has the double effect of increasing the efficiency of the anchor and of providing a spring which aids in damping out the effect of snatch in a swell. The impossibility of carrying chain led to the investigation of the effects of a canvas bag filled with shingle and made fast at a suitable position on the anchor line. These experiments were carried out with anchor F.

The holding power of the anchor is increased very considerably with a weight added to the line up to 50 lbs., but further addition causes the holding power to be increased by little more than that of the extra weight. The first 50 lbs. causes the pull on the anchor to be horizontal, *i.e.*, to operate at its maximum efficiency, while weights in excess owe their holding only to the friction on the bottom. It is therefore uneconomical to increase the weight added to the line above that necessary to cause the anchor to pull horizontally.

The effect of using chain instead of rope and a weighted bag was also tested. The employment of chain cable is equivalent to weighting the anchor line with a large number of distributed small weights.

It is unlikely that varying designs of anchors will benefit to the same extent by the fitting of a weight to the anchor line. This is a point that can only be ascertained by experiment with individual anchors; but it does suggest an economical method of anchoring. It has been ascertained that the weight has most effect at a given position on the anchor line; in the case quoted it was 35 to 40 feet from the anchor.

It is proposed to adopt the expedient of fitting a stop on the anchor line at this point and to anchor in the normal manner. Canvas bags, which are carried for the purpose, will be filled ashore with shingle, scrap iron or similar material, and slid down the line to the stop. In practice special ballast for the purpose need not be carried, since in emergency any equipment in the flying boat like tools, spare ammunition trays, etc., could be utilised. The expedient has already given successful results in practice. A flying boat in Dover harbour, sheltered from the worst of the swell, held satisfactorily in a wind which exceeded 40 miles per hour, using a Felixstowe Mark 5 anchor and a bag filled with 100 lbs. of shingle.

Stowage of Anchors

Except for minor experiments in designing a folding anchor, which have not been pressed forward until greater efficiency has been achieved, little has been done to arrange for an anchor stowage. As flying boats increase in size and the surplus weight available for an anchor becomes greater, two points are likely to predominate. The first is difficulty in handling the anchor into the flying boat, and the second is the advisability of arranging for it to be dropped at short notice. The solution will probably be to arrange the anchor so that it is permanently outside the hull and can be weighed by the use of a small winch. The problem of the position of the anchor as an additional parasitic drag is one for the aircraft designer to solve.

Equipment for Manœuvring on the Water

The first lesson which is forcibly thrust on the seaplane pilot is the almost uncanny behaviour of motor boats. Of the incidents involving damage to flying

boats which have come under my personal notice during the past six years, two are attributable to forced landings in heavy seas, three to heavy seas whilst taking off, three to structural weakness of hulls of unsuitable design, and a relatively large number in which the prime cause was relying on a motor boat for manœuvring the flying boat. For reasons of safety, if not of independence from outside assistance, the ability to manœuvre in all situations without recourse to towing is of paramount importance.

Drogues or Sea-anchors

Perhaps the most useful piece of equipment carried by the flying boat is the drogue or sea anchor. It is usual to fit one of them on either side of the hull, the point of attachment frequently being that of the wing root struts to the hull. Experience has shown that the most suitable length of wire used for the tow is such that the drogue rides level with the after step. When fitted in this position it is suitable for taxying at slow speeds whilst retaining the high degree of steerage necessary when entering congested areas, and when mooring up or casting off. With one outboard engine stopped, the use of one drogue in conjunction with the running engine aids the keeping of a course against the turning moment of the engine. With all engines stopped, drogues are used to retard the drift of the flying boat due to the effect of the wind. For the two latter purposes it is advisable to have the drogue readily detachable. When taxying for long periods on an outboard engine becomes necessary, it is found to be an advantage to obtain the full effect from the drogue by attaching it to a point near the wing tip. When drifting it is preferable to carry a much longer line from the bows. Loss or damage to drogues is not infrequent, and is usually due either to inexperience in their use or to the need of sudden bursts of engine in emergency. By inserting a short length of shock absorber to their mounting, the initial strain has been reduced and their life lengthened.

As flying boats increase in size, so it has been found necessary to fit larger drogues. The openings of cockpits have however remained unchanged in service aircraft, restricting the maximum diameter of the drogue that can be used. Three methods are under consideration:—

(1) Making the drogue oval-shaped with the smaller diameter suitable to the cockpit opening.

(2) Hingeing the hoop of the drogue so that it can be folded.

(3) Fitting two standard drogues in tandem.

Promising results have been obtained by the second and third methods, but both are open to disadvantages that will be obvious.

The present method of attachment of the drogue cable to the wing root struts leaves a length of slack wire exposed in the air. There seems to be little reason, particularly in metal hulls, why the cable should not be fitted at a convenient position on the hull from which it can be readily detached and the whole taken inside the hull.

Little attempt has been made to arrange suitable stowage for drogues. It is not only inconveient to have wet masses of canvas lying in the bottom of a hull, but it is a direct incentive to corrosion. The metal Southamptons equipped for the Far East flight have a stowage in the lower centre section, a bag arrangement almost flush with the wing being employed. This is not ideal for various reasons. As a general principle it may be stated, that gear should be so arranged that it can be stowed within the hull when in flight on all possible occasions. It is suggested that drogues should be stowed in light metal cases independent of the main structure, and provided with drain holes which empty into the open. In the event of corrosion of the case its replacement from time to time is a simple matter.

Mooring Boat Hooks

Each flying boat is provided with a boat hook for the purpose of picking up moorings. At the present time this consists of a shaft of a length varying with the height of the bows, and a spring hook to which is attached a suitable rope, the end of which is made fast to the flying boat. A modification consists of a hook which on closing on the ring, detaches itself from the staff and prevents the latter from being smashed.

One small particular type of seaplane has been provided with a boat hook of which the shaft is made of a light alloy, and there appears little reason why this should not be adapted for use with flying boats. The replacement of the usual ash handle by one of light metal not only results in a considerable saving in weight, but also assists ease in handling. Little difficulty should be found in bending the staff straight again in the event of damage, and corrosion can practically be ignored.

A normal type of hook fitted on the opposite end of the mooring hook is a useful modification for countless purposes.

Dinghies

Numerous attempts have been made to provide dinghies suitable for being carried in a flying boat. At the present stage of development it must be doubtful if we are justified in adding this additional load to the already overburdened seaplane. In practice the weight available for a dinghy is so restricted that it appears impracticable to build one suitable for operation in anything but the calmest water. If it is to be regarded as a raft for use in emergency, and as such is intended to replace the weight of flotation jackets at present carried for the crew, it would hardly be justified. Actually it will be more economical to develop a combined floating and flying suit, or to utilise inflated cushions in the case of commercial flying boats.

Dinghies actually tested are of three types, which may be classified as inflated, folding and rigid.

(*a*) The inflatable type consists of an oval-shaped rubber raft, the periphery of which is of hollow rubber which can be blown up by a hand pump. The time taken to inflate may be ten minutes, but small cylinders containing carbon dioxide have been designed for use in emergency. Its disadvantages are that the rubber is liable to damage and deterioration rapidly. Its advantages are that it can be stowed into a small space and that as long as it remains unpunctured, it would support a crew of five or six.

(*b*) The folding type has many variations. It has been constructed with a light ash frame-work covered with canvas, and also combined with the inflatable type, and one of the most successful has consisted of thin sewn wood with canvas hinges combined with a surround of floating material. This type has the advantage of being stowable inside a hull and can be assembled rapidly on the centre section. But in emergency it definitely relies on the amount of floating material in its construction for the buoyancy afforded to a crew.

(*c*) The rigid type has been built in both wood and metal, and provision has been made for attachment outside the hull. It relies on water-tight compartments for remaining afloat when flooded. It is the strongest of the dinghies used; rapidly available for use, but heavier than the other types.

My present personal feeling is that the dinghy is an expensive luxury, of limited use, and that its chief interest lies in its possible application to very large flying boats of the future.

Refuelling Equipment

It is hardly an exaggeration to say that in the past, flying boats have spent more time in refuelling on the water than they have in the air. The problem of rapid refuelling on the water is of vital importance both to service

and commercial aircraft, not merely for the economised time and for conservation of man power, but to some extent to minimise the period during which it is necessary to keep the aircraft in a position which occasionally verges upon the dangerous while refuelling is in progress.

Petrol may be received in a variety of containers, depending on the part of the world visited. It may be in steel barrels varying in contents from 40 to 60 gallons, it may be in 5 gallon drums and in 2 or 4 gallon tins. Until seaplane bases exist with standardised equipment all along possible routes it is necessary to legislate for all these contingencies. Further, until requirements are realised, or until the demand for fuel warrants commercial enterprise laying itself out to supply fuel direct to the aircraft tanks, it is necessary to carry the complete refuelling equipment aboard. This will hardly weigh less than fifty pounds. It is to be hoped that the time may come when the need for carrying this additional weight in aircraft may disappear with the advent of adequate ground organisation. Even now it may not be inopportune to offer one suggestion to the civil side. It is strongly suggested that international agreement should be aimed at forthwith to standardise the methods of refuelling. It is appreciated that the present necessity is not apparent, but greater difficulty in obtaining uniformity will be experienced as needs grow. The fundamentals established, little difficulty should be found in obtaining the adoption of hoses and couplings of fixed dimensions at all air ports.

Conditions vary so very much that the plant now carried must be adaptable to all conditions. The petrol may be delivered in a lighter, a motor barge, or a steam drifter; it may be left on the wall of a quay, at the end of a pier, or on the beach itself. When it is in barrels the supply is almost always centralised, so that only one aircraft can be refuelled at a time. Thus when several flying boats are operating together it is a distinct advantage to be able to concentrate all available pumping resources.

The modern tendency is to arrange the aircraft petrol tanks on the top plane, and with the larger types it is quite out of the question to pass up tins, not only from a handling point of view, but also from the number of men required and the time factor.

Refuelling apparatus designed to fulfil all conditions is necessarily somewhat bulky. It consists essentially of a container, into which cans may be emptied, thence an outlet leads to a high speed filter, thence to the petrol pump and through a hose to the aircraft tank. The pump is conveniently mounted on the side of the container, which has collapsible feet fitted so that it may be held rigid in operation. When it is desired to refuel from barrels, the pipe from the base of the container is disconnected and a hose is fitted direct to the filter to which petrol is drawn straight from the barrel.

The use of chamois leather for filtering petrol precludes all hopes of speeding the refuelling process, and from this point of view it is necessary to utilise a filter composed of fine mesh gauze. The Zwickey filter has given satisfactory results. One filter has been found adequate, and when fitted on the inlet side of the petrol pump has prevented failure of the latter, through the introduction of foreign matter.

The limiting dimension of the hose is the diameter of the petrol barrel bung, which differs considerably in various countries. "Hammond" hose with an internal diameter of $1\frac{1}{4}$ inches has fulfilled the majority of conditions and is of a reasonable weight. All connections of hose, filter, pump and petrol tank must necessarily be the same, and a gas thread of $1\frac{1}{4}$ inches has been provisionally standardised. Practice points to the desirability of adopting a length of 30 feet for the delivery and 20 feet for the suction hose.

All couplings require screw dust covers and each cover has to be suitably secured to prevent loss when the plant is in use; kite cord has been found preferable to the commercial brass chain.

The couplings are made hexagonal and a set spanner (also attached to the plant when not in use) is carried. Brass couplings with short protruding tommy bars were more convenient, but broke under continual use.

The wisdom of fitting washers which will remain *in situ* and are easily replaced, will be realised.

It is advisable to make all metal fittings of the refuelling plant of brass or gunmetal, since they will receive the minimum of attention, and corrosion of threads, etc., is liable to be serious.

Various pumps have been tried, but one having all the desirable features of capacity, simplicity and lightness has not yet been found. It is considered that a capacity of 600 gallons per hour as a minimum is required (this probably represents rather less than 500 gallons in practice due to working delays) and that combined with a filter this should be obtainable for a weight of 20 lbs. It is thought that little will be gained by ounce paring, as robustness is essential. Curiously enough experience has shown that it is an advantage rather than an objection to legislate for two men to work the pump at the same time; two men working together have roughly the same capacity as three working independently.

The remaining item in the refuelling plant which needs examination is the aircraft tank. With tanks in the top plane, it is most convenient to fit the petrol hose attachment to the base of the tank, the petrol being led up through a stock pipe whence it overflows into the tank. It should be arranged that the petrol is not discharged in the close proximity of the air vent, or splash will cause petrol to be blown out with the air which is being expelled. It is convenient to have an overflow cock or similar indicator to show positively when the tank is full. It is a great advantage to fit a drain cock of adequate size at the lowest point of the tank. This not only admits of readily draining the tank when damage occurs, but it acts as an additional cleanser for the petrol. It is desirable practice at frequent intervals to drain the bottom gallon out of the tank and thus to remove water, etc., which may have accumulated.

When it is possible to foresee that petrol will only be delivered in one size container, for example in barrels as was arranged on the recent Baltic cruise, the necessary plant can be simplified and the pump mounted on a suitable portable trestle.

By good organisation, refuelling can be made rapid. Using the methods outlined, one flying boat during the cruise refuelled with 800 gallons in 35 minutes, despite the low capacity of some of the pumps. On several occasions 2,000 gallons in all were taken in by four boats in a little over two hours.

One further point in connection with refuelling is possibly worthy of mention. Frequently when visiting foreign ports the fuel comes out in a heavy motor lighter. The flying boat is brought up astern and held in position with its bows alongside the lighter and the counter of the latter is just ahead of the wing. Lines are made fast from the stern of the lighter to the bollard on the bows of the flying boat and to the base of the outer forward wing strut. In a moderate swell, heavy strains are imposed on these points in abnormal directions, and the necessity for providing adequate strength should be appreciated. A suitable rubbing streak on the flying boat for craft alongside is a valuable preventive of damage.

Bilging Equipment

Fortunately advance in design has almost eliminated that bugbear of leaky hulls. One flying boat did not require bilging during the whole of the Baltic cruise.

Simplicity is the keynote to bilge pumps. They are the most neglected piece of equipment, receiving attention only when everything else is done, which is rare.

Experience has shown that the old-fashioned plunger type, fitted with large valves depending upon gravity for their action, is the most suitable. It must be constructed of a non-corrosive metal, and must be easily taken to pieces. The suction hose needs internal and external armouring, and a coarse filter is necessary to prevent small particles of foreign matter accumulating in the bilges. A capacity of 300 gallons per hour is probably adequate, it being borne in mind that only water which has accumulated through imperceptible leaks, and not due to holes caused through actual damage, has to be dealt with.

The bilging of wing tip floats is sometimes necessary, but except in very rough weather it is usually practicable to remove the drain plugs. These should be of reasonable dimensions and made of a non-corrosive material, strong enough to admit of a tool being used upon them without causing burring. Aluminium alloys are quite unsuitable for the purpose. It is an advantage if the plugs are attached to the float to avoid their loss when unscrewed.

Engine Equipment

In the past little consideration has been given to the needs of the engineer struggling to maintain his engine on a flying boat afloat. Foot-rails and steps all savour of after-thought. It is a thankless job working in wind and rain with a swell inviting sea-sickness on a ledge so unstable that only one hand is available to use a tool. Wide detachable footboards, rigidly fixed when in use, are necessary, arranged at a suitable height for working with some degree of comfort.

When the engine is cowled in, a number of spaces occur where trays could be fitted for containing tools and small parts, and this provision would be appreciated. The losses caused by personnel unused to working on the water is at present considerable.

An attempt has been made to fit a small bench and vice in one flying boat on an extended cruise, as well as suitable drawers for tools and a small paraffin bath. With service craft on detached duties, such a factor would be invaluable and it becomes practicable in the large sizes.

Ability to change an engine afloat is a considerable advantage. With improvised gear this was demonstrated in 1924 and again in 1925 when the necessity arose on actual cruises. The incorporation in the equipment of a flying boat of successful apparatus capable of being carried in the air was performed by Messrs. Short Bros. and later by Messrs. Supermarine. This equipment has the advantage of allowing the engine to be removed whilst the boat is at its moorings without the assistance of a friendly quay where a crane or derrick may be available.

Living Aboard

To live aboard the small type flying boat and to carry out operations regularly whilst so doing, is practicable for very short periods in fine weather, but it ultimately leads to a loss of efficiency due to the limitations of space and weight. With increase in size, this desirable feature may become necessary, but it is debatable whether the comfort of the crew should not be sacrificed at the present juncture to obtain a range which will more nearly meet service requirements. Living aboard would then occur only when local conditions imposed it and arrangements would be improvised.

For general considerations, fundamental features are absolutely necessary:—

(1) Adequate head room.
(2) Passage free from obstruction.
(3) Floor flat, or where steps are necessary over transverse bulkheads, they should be so wide that both hands are free when negotiating them.
(4) A water-tight hull, both below and above water.

Apart from the effect of colour of the interior of the hull on the disposition of individual members of the crew, it is necessary to aim at obtaining light with the minimum expenditure of work on cleaning paint work. Hulls painted white throughout necessitate continual scrubbing. It is considered better to leave the top of the interior of the hull white and to paint from waist-high downwards with grey or other suitable colour. Overhead electric lights are necessary, but their positioning requires careful thought.

Ventilation by means of portholes which are fitted with water-tight rims is advisable and means should be provided for rapid replacement of cracked glass. The portholes should all be of the same size and shape so that the glass is standardised.

In tropical countries an electric fan is required and the open cockpits need to be covered with a canopy. The latter is sloped down slightly aft in order to make a wind sail to assist in driving air into the hull. The boat hook is frequently used for its front support and wires stretched between the engines take the weight aft.

Washing and Lavatory Arrangements

I have purposely chosen these subjects before discussing cooking and sleeping, because they are the crux of the whole matter. Little or no attempt has been made to solve problems of personal cleanliness on flying boats. With a crew of five, an allowance of washing water of a gallon a day per head does not seem excessive, but with tankage it may add an additional 60lbs. However hard you may strive to eliminate dirt, you cannot keep clean while working on an aircraft, and one wash a day is hopelessly inadequate. A communal bath is at present a fantastic luxury, and it would be a courageous man who would dare to hint its necessity to designers. A proper wash bowl, with water laid on, and a drain is required. Its position should be such that it can be utilised in a standing position. On long flights the advantage of being able to refresh oneself with a wash must be experienced to be appreciated.

It must be possible to use the lavatory on the water and it is suggested that the standard marine practice in small boats could be copied with advantage.

Cooking Equipment and Food Storage

A stove utilising atomised paraffin, with a double burner so designed that it will keep burning in a breeze, has proved generally satisfactory. The heating fuel to light the stove is carried in tablet form.

The cooking utensils consist of a kettle, a frying pan and a saucepan, all made of iron. It must be remembered that they are washed up in salt water and aluminium ware is unsuitable.

The crockery includes one plate and one cup per member of the crew together with knives, forks and spoons, and one teapot.

Special stowage is necessary for food and it can be made conveniently from duralumin with ventilation holes guarded by gauze. This is necessary as flies seem to accumulate directly food is brought aboard, indeed some flies collected in France remained in a "Southampton" despite organised hunts during the flight to Egypt and back again to England, where they finally succumbed to the weather.

Tins for sugar, tea, salt, pepper, etc., are used, while milk powder like Glaxo is found easier to keep than liquid condensed milk.

The food suitable for consumption has to be carefully censored by the captain of the flying boat, as attempts at cooking certain kinds of fish have resulted in the interior of the hull becoming untenable. The ultimate result is a falling back on to tinned foods, especially abroad.

A table is necessary to eat at or confusion reigns, and some form of ritual has to be introduced into meal times. The personality of the captain enters

greatly into this, and his enthusiasim and appreciation of the cook's products and cheerful acceptance of unsavoury efforts goes much to make a " happy boat."

Beds and Bedding

Canvas spread over a light frame-work has been found more satisfactory than hammocks for sleeping. White canvas which is arranged readily detachable for washing is found preferable to Willesden green which stains easily.

Light sleeping bags with water-proof linings form the best bedding, and can be used with a certain degree of comfort on the floor or in the open, should the necessity arise. A pillow is incorporated in the head of the sleeping bag.

A conservative estimate of the additional weight which has to be carried for a crew of five living aboard is 250 lbs.

General Purpose Donkey Engine

The provision of an auxiliary motor to cope with much of the work now done by hand has long been mooted. The first attempt to fulfil some of the functions is just seeing daylight in one commercial flying boat. The engine starting motor is arranged to drive a bilge pump and to run a wireless generator in emergency.

The design of a donkey engine which will also pump petrol, charge accumulators and run a capstan for hauling up the anchor, etc., may be a requirement of the immediate future.

Future Equipment for Flying

It will be observed that the present paper has dealt with equipment utilised on the water at considerable length. Since the foundation of flying is this water organisation, such a procedure is inevitable, and it is proposed now only to outline some of the main factors which have impressed themselves as future requirements in the air.

The flights carried out at present cannot be described as being of long duration, ten hours probably being the maximum, but they give some indication of what may be anticipated when they are increased to twenty hours.

The main features likely to be found necessary are:—

(*a*) Reduction of causes which produce fatigue.
(*b*) Attention to the comfort of the crew.
(*c*) An increase in the number of the crew.
(*d*) A high degree of stability combined with mechanical aids to flying.
(*e*) Efficient inter-communication.

(*a*) *Reduction of Fatigue.*

My impression is that fatigue is caused by exposure to the wind and weather and to insufficiently silenced engines.

There seems little reason why the pilots could not be completely enclosed, windows being capable of being raised or lowered as in car practice. Eye strain can be minimised by fitting wind-screen wipers (no suitable type is known to exist at present) and by regrouping instruments so that only the essential ones are under the pilot's eye. Instrument designers may produce a distant reading revolution counter which can be fitted on the dash; any position on the engine mountings is impracticable for night flying, and is necessarily an additional cause of fatigue.

A petrol gauge giving accurate readings of fuel contents remaining is still to seek. The hit and miss method is invariably a cause for anxiety.

(*b*) *Comfort of the Crew.*

This will include ease of movement within the hull, probably a " silent " wireless cabinet, and a protected compartment in which the watch off duty may

sleep. A regular service of hot meals in the air will be required if such flights are going to be carried out repeatedly.

(*c*) *Increase in Crew.*

It is possible that three pilots (who can also carry out navigation), one engineer per engine, a rigger, two wireless operators and a cook, making a total for a three-engined flying boat of ten, will be carried.

(*d*) *Stability and Mechanical Aids.*

A stable aircraft is not merely restful to the pilot, it is reflected on the crew, who are not compelled, unconsciously perhaps, to conform to continual movement laterally and longitudinally. Devices to control the course of the aircraft will not only relieve the pilot, but will maintain greater accuracy than is possible by solely human means.

(*e*) *Inter-Communication.*

Communication between members of the crew still remains in the pencil note stage. The urgent necessity for efficient telephonic communication, particularly in service aircraft, should hardly need confirmation.

Conclusion

In the opening paragraph of this paper I mentioned that detail has necessarily been emphasised throughout its course. I can only hope that the trees have not hidden the wood.

May I take the opportunity of thanking Wing-Commander Maycock and Major Ledeboer, who have discussed, criticised and aided, while they have not always concurred in the views expressed in this paper.

Discussion

The Chairman said there could be no doubt whatever that this paper was the first published in any country which dealt authoritatively and exhaustively with the many problems facing those who had to operate flying boats, whether for civil or military purposes. It would be read very diligently by everyone who was trying to operate or was thinking of operating flying boats, because it was based upon the experience of Flight Lieutenant Cross and the other officers of the Royal Air Force, who were qualified to express opinions. The cruise now being undertaken so successfully under Group Captain Cave-Browne-Cave, and the publication of a paper such as that of Flight Lieutenant Cross, were pointers in the direction of the development of the flying boat. The Director of Civil Aviation had not yet been successful in establishing a civil flying boat service, but he had one in mind, and the paper would be interesting to his department and to Imperial Airways, Ltd. Perhaps he would say what proportion of the money now available was going to be devoted to the development of the flying boat, which had been so badly neglected so far as civil flying was concerned.

Air Vice-Marshal Sir Sefton Brancker said that as Director of Civil Aviation he owed a great debt of gratitude to Flight Lieutenant Cross, the officer who had done more than any other in the Service, he believed, to push the use of flying boats. He (Sir Sefton Brancker) had learned a great deal from the paper, and he was going to worry Flight Lieutenant Cross a good deal in the future for further advice. A very interesting problem on which he would like his views was the comparative efficiency of the three types of flying boat—the boat with stabiliser fins like the Dornier Wal; the boat with floats directly under the engines, such as the Rohrbach; and our own boats with wing-tip floats. Sir Alan Cobham's experience at Malta recently, suggested that the wing-tip

float was a very distinct weakness in the operation of flying boats. He asked if Flight Lieutenant Cross considered the biplane or the monoplane to be the better type of machine, assuming that it was necessary to carry at least three engines in a big boat. A point which was not mentioned by Flight Lieutenant Cross was the possibility of aircraft "flying" at their moorings. He had heard of such things happening, and he asked if there were any standard and approved method of preventing it in a high wind of 60 or 70 m.p.h. He supported Flight Lieutenant Cross's remarks with regard to the standardisation of fuelling methods, and proposed to bring this matter forward for discussion at an international conference in the near future. The only trouble was that we should probably have to follow to some extent other people's methods, because we were a long way behind other people in the operation of flying boats; for instance, Germany and France. He was very pleased to note that Flight Lieutenant Cross, as the result of his experience, had recommended the covering of the cockpit and of the pilot and crew. It was important, particularly in very hot and very cold climates, and he believed the Americans and the Germans were adopting that practice. The suggestion that a flying boat should carry a crew of ten had filled him with horror. One of the great difficulties of air transport was the constant demand for a larger crew. In the big aeroplanes of to-day one could make use of a crew of four or five. For instance, it would be very nice to carry two pilots, a navigator, a wireless operator, a mechanic and a steward; but this was impossible from the commercial point of view, and one of the problems at the present time was whether it was better to turn a wireless operator into a mechanic or a mechanic into a wireless operator. With regard to floating docks, Sir Sefton said he had made efforts to get a new one built, but the shortage of money had prevented it. He believed the use of such a dock was the right solution to many problems, particularly in the early stages of operations, when one could not quite make up one's mind where to have the air port, and when one wanted to avoid large expenditure. A floating dock was comparatively cheap and could be placed where it was wanted at any time. He asked Flight Lieutenant Cross whether, as the result of his experience with the existing dock, which was eight or ten years old, he could produce a really good specification. He was unable to reply to the Chairman's request with regard to the money to be devoted to flying boat development. There would be a considerable alteration, however, in connection with the subsidy to Imperial Airways, which would give the contract with them a really Imperial flavour instead of merely a European one, and when that alteration was effected there would be considerably more money available. He hoped to see the first two "Calcuttas" on some portion of the route between this country and India before very long, and hoped also that Imperial Airways would be ordering more boats. He would like advice as to what should be our next step in the development of flying boats. For instance, should we adopt the use of four engines? We wanted boats which would jump a little further than the "Calcutta" would jump, with a paying load. A boat which would be very useful, he believed, was one which would cross the Mediterranean from France to Malta and from Malta to Egypt without re-fuelling and carrying a really appreciable paying load.

Mr. SHORT: With regard to floating docks as a means of handling large flying boats and seaplanes, in 1913 he suggested the use of such a device to the Admiralty, but it was not until after the War that a flying boat dock came into existence in Great Britain. The particular example, though useful, was so expensive as to retard any further development.

It should be possible to build much less expensive docks costing from a few hundreds to a few thousand pounds at most, and their use could undoubtedly do much to solve the problem of maintenance of flying boats in service use.

Major RENNIE, referring to the proposal that the pilot's cockpit should be closed in, said he had suggested that on several occasions, but the pilots who

had been consulted had said that it was better that the cockpit should be open. Not only was the closed cockpit better from the point of view of comfort, but it had been found also that the effect of closing in the cockpit was to decrease the air resistance of the hull at least 25 per cent.

Mr. CHORLTON, commenting on Sir Sefton Brancker's remarks with regard to the different types of boats, expresed the view that we in this country had tied our practice rather too much to one type. He had heard that the Rohrbach type stood up remarkably well in heavy weather, but had not personal experience as to whether that was so or not. It would be valuable if we took account of what other countries were doing in this connection. If very large boats were developed, he hoped there would be a chance of using the heavy oil engine. When boats carrying four engines, each of about 750 h.p., were used, and when the auxiliary equipment was arranged to serve all four engines instead of one, there would be a chance for the heavy oil engine to show how efficient it was. It should not be overlooked that this fuel had a higher viscosity that petrol, *i.e.*, it flowed less easily and, of course, would be affected to a certain extent by cold weather. Equal care had to be taken to ensure that it was perfectly clean for service.

It was rather alarming to learn that for every engine installed in a flying boat an extra man would be required to look after it, and it seemed that with this generosity the crews might become larger than the boats would carry. To say that each engine required a man to look after it was a reflection on the engine, and engineers should give attention to the problem with a view to obviating the necessity for that, if it were true. He hoped the developments foreshadowed by Sir Sefton Brancker would take place quickly, and that we should soon have in operation really large flying boats capable of making 2,000-mile flights with certainty and reliability, according to schedule time.

Mr. A. GOUGE said that Flight Lieutenant Cross was a flying boat pilot of very wide experience, and his opinions on the equipment of flying boats must be treated with respect. Mr. Gouge asked if Flight Lieutenant Cross had any experience of the effect of the position of the wing floats upon the yawing of a flying boat when being towed from a central point in the bows. It would seem to him that the correct positioning of wing floats might do away with this yawing, and so reduce the necessity for using the Yarmouth towing gear. He also asked if any attempts had been made to produce an elastic link in the mooring cable. His experience had led him to believe that the maximum loads in a mooring cable were in the nature of an impact load, and if this were so the elastic link should greatly reduce the loads. It was with horror that he had heard Flight Lieutenant Cross say that the anchor should hang from the bows of the hull, and should have the necessary equipment for raising and lowering it. Was this anchor absolutely necessary in the case of a flying boat operating between two bases with proper mooring equipment at each base? Was it not more an item of equipment for craft making pioneer flights? In any case, it seemed to him that anchors of the weight stated would be of very little use if there were a real wind blowing. He also asked for the opinion of Flight Lieutenant Cross on the method used by Imperial Airways at Southampton when bringing their flying boat up to a mooring. He believed he was correct in stating that they did not carry drogues; these were carried by an attendant motor boat and were fixed to the flying boat after it had "landed." It would seem that commercial flying boats might need treatment different from that given to naval craft. Finally, with regard to docks, he said it appeared to him that we should eventually arrive at a type similar to that used for ordinary surface boats, *i.e.*, a dock cut into the land, and into which the flying boat might be towed at high water, much in the same way that sea-going vessels were treated to-day.

Major BRACKLEY said that the advice given in the paper would be of great use to Imperial Airways when they had some flying boats. With regard to the statement by Mr. Gouge, that the Imperial Airways machines did not carry much gear, he said that obviously they could not, or they would have no paying load. The standardisation of fuelling methods was an important matter, and the problem of engine equipment was one which required a great deal of attention. The Imperial Airways machines would not be able to carry a large number of engineers, but attention should be given to the provision of platforms such as those erected on the "Calcutta," and they should be developed in order that the crew could carry out their duties more comfortably.

Squadron Leader ENGLAND said the lecturer had dealt fully with the equipment of the flying boat, and had emphasised the need of producing a motor boat which could be operated with flying boats, without damaging the latter. This appeared to be an inducement to motor boat manufacturers to produce a more usable craft.

He heartily disagreed with the lecturer advocating the anchor on the bows; because if higher speeds were to be obtained, drastic cleaning up was necessary. He would like to know if the lecturer could disclose the dimensions of the Felixstowe Mark 12 anchor, and also whether tests have been made as to fixing a weight to the anchor chain, and if so, whether the tests were carried out on different holding grounds, such as shingle, sand, mud, etc. His personal experience was that the weight acted well in the case of mud, but not well in other holding grounds.

He was surprised to hear so experienced a flying boat pilot as Flight Lieutenant Cross advocating the carrying of the drogue inside the hull. One of the greatest difficulties was to keep the hull dry. If, therefore, the drogue was to be kept inside, it would further add to the complications. The obvious place for the drogue appeared to be in one of the centre section stub planes.

The paper would lead one to believe that bilging equipment was hardly necessary nowadays. He ventured to suggest, however, that it was, as in taking off or landing in rough seas where a good deal of sea was shipped into the cockpits, for the comfort of all concerned it was necessary to get rid of this water; and again, accidents invariably happen, such as striking an object on the water, which might hole the bottom of the boat. With a sufficiently powerful bilge pump the machine could be saved, whereas with a slow bilge pump the result may be somewhat serious.

The engine slinging gear arrangements were interesting and he would like to know if tests had been carried out under service conditions.

There was no doubt that the crew of the flying boat should be totally enclosed. This would in a large measure reduce the fatigue caused by the wind and noise. In the flying boat, however, the difficulties were somewhat great, in that drumming or vibration took place in the hull which required investigation in order to eliminate it.

He saw no reason why it should be necessary to have such large crews as the lecturer had advocated, in fact should this be necessary, the flying boat had little future. During the Great War long distance flights were carried out with gyro motors, or as they were now called, automatic pilots; why, therefore, should a spare pilot be carried? It seemed to him entirely unnecessary if a gyro or automatic pilot could be substituted.

In conclusion, he felt that until the instrument question was tackled afresh and all instruments brought within easy vision of the pilot, without having to be continually looking behind him, there would always be difficulties raised in totally enclosing the pilot and crew of the flying boat.

In flying boats and large twin-engined aircraft, where the pilot was situated ahead of the engines, he was of opinion that the electrical revolution counter was very much needed.

Major SIPPE said that they had not dealt with the provision of adequate methods for launching and beaching aeroplanes and flying boats. When he was at Brough at the end of the War there had been the greatest difficulty in this connection owing to the fast current of the river during the rise and fall of the tide. It had been suggested that a dock should be installed, and another idea was that there should be a travelling crane; but although a great deal of thought was given to the question, he ultimately had to rely on the old method of sending men into the water in bathing suits. Even in present times this inadequate and dangerous method, to men and machines alike, is being employed in Royal Air Force stations, and he strongly recommended those responsible for Civil Aviation schemes to go into this matter closely when considering the employment of flying boats or seaplanes.

Wing Commander T. R. CAVE-BROWNE-CAVE, referring to the author's tables relating to anchors, pointed out that the anchor supplied for use with Short 184 type float seaplanes had a holding factor of 13.6, as against a holding power of 11.3 in the latest Felixstowe anchor. It seemed to him, from the picture the author had shown of the Felixstowe anchor, that by adopting something more or less similar to the Martin stockless anchor we should get an effective anchor which would also haul close into a hawse pipe very neatly and would give practically no drag.

He said that the chain cable had a two-fold advantage. Its considerable weight acted as a spring and relieved the anchor from the impulsive tugging of the boat; and secondly, it stowed conveniently. The author had shown how a concentrated weight could be used to act as a spring more effectively than a heavy cable. It appeared, however, that a properly designed cable of high tensile material would be as effective as a wire of the same weight and would realise the second advantage of being handled and stowed much more conveniently.

The author had suggested that the point at which the mooring wire was attached should be moved further aft, to a point subject to less vertical movement. It appeared probable that the boat would then lie less truly head-to-wind or head-to-tide, and the forces on the boat would be considerably increased in consequence.

All the flying boat drogues he had seen had some rigid part. The drogues developed for airship work during the War developed a higher resistance than the conical type when tested in the N.P.L. tank. They had the added advantage that stowage was easier and there was no rigid part.

The author when referring to fabric boats had omitted to mention the type made of rubber-proofed fabric and inflated by low pressure bellows. That was the type carried as standard in the North Sea airships during the War, and had proved entirely satisfactory. The same type had proved the most satisfactory with the Far East cruise, and when the flying boats had descended unexpectedly at Ramadie, on the Euphrates, had been the only available means of getting fuel to them.

Discussing the difficulties of the mechanic, when trying to work single-handed on an engine of a boat which was rolling on the water, he suggested that the over-alls, or flying suit, should be fitted with a belt at the height of the chest, and a hook on a strap a few inches long, so that the mechanic could secure himself to any convenient part of the structure of the boat. He could work with greater safety and could use both hands. Such belts would also be very useful if a man fell overboard, because it would be far easier to hook on to a lift line than to hold on to it.

With regard to donkey engines, he said that if the fuelling of the boat, or the weighing of the anchor, or the working of the bilge pump were made dependent upon a small engine, that engine must be very reliable—an ideal not usually realised.

As to the author's suggestion that the result of increasing the length of flights would be to impose much more exacting conditions upon the crew, he said he had not sufficient experience to enable him to express an opinion, but had heard it suggested that the hours spent in actual flight were far less exacting than the hours spent on the water in preparation. Possibly the main result of increasing the periods of flights from 10 to 20 hours would be that the amount of petrol to be taken in would be doubled. From his experience of long airship flights, he agreed that there was a very great need to provide hot food, but only in a passenger demonstration flight, where luxury was aimed at, had they ever carried a special cook. Indeed, on ordinary flights, the difficulty was to prevent the members of the crew, who were off duty, from spending their time cooking; it was their one passion.

Mr. W. O. MANNING said the author need not have expressed any apology on account of the fact that his paper dealt with detail, because detail was of the utmost importance. With regard to anchors, he asked whether the holding factor of a particular type of anchor would remain the same if the size of the anchor were increased; in other words, was there a scale effect? As to the refuelling arrangements and the suggestion that the filter should be on the suction side of the pump, he said the filter was usually on the other side, because there was a possibility of pieces of packing or fragments of leather from cup washers becoming detached and causing trouble.

I think it would add interest to a most valuable paper if the author would include a list of tools (spanners, pliers, etc.) that he considers should form part of the outfit for an extended cruise.

Captain NICOLSON: Dealing with towing arrangements, the present practice of towing flying boats is to attach the bridle from the keel to the centre of deck at the bow. My experience of towing high speed motor boats, which are delicate craft and very similar to flying boat hulls, showed that by attaching the bridle to the chines and the line running horizontal instead of vertical, this method arrests the tendency to yawing and prevents ploughing.

Flight Lieutenant Cross should be congratulated on dealing at length with the question of anchors, as this is a most important part of the equipment of any seagoing craft. Shipbuilders did not pay the necessary attention to this scientific side of their problem, as they usually carried anchors heavy enough to ensure the ship would not come adrift, but with flying boats, weight was of primary consideration, and here the author must have spent a good deal of time on practical research.

In my opinion the length of chain or cable is nearly as important as the type of anchor; and the quantity of cable to ride by will depend upon the nature of the bottom, the strength of the wind and tide. Generally speaking, three times the depth of water at the top of flood is sufficient for a moderate calm berth.

For motor boats and yachts anchors are chosen according to the total weight of the boat, including her ballast and all equipment. I have had a very considerable experience with many types of anchors, and found that with a long shank and convex elongated palms, this had the maximum of holding power, and consequently could be used lighter than any other anchor.

In my opinion the length of shank must exist to get the holding power, and the arms should not be shorter than .4 of the shank, nor made a less angle than 55° with the shank.

Several anchors have been designed and built to hinge and fold up. Among these I found the Gales' Improved Trotman to be very compact, and snug when berthed and is very efficient in shallow water. The usual objection to hinged anchors is that the crowns are weakened, but with the Sinnettes anchor the crown joint is exceptionally strong, so the foregoing objection does not exist in this anchor. This anchor has a tapered pin and tapered hole to receive it, so is

much better than the parallel pin which often jams and requires a hammer to get it out. In another form of this anchor, the arms are not locked when in use, but only for stowing. The arms have back flukes and the upper arm falls on the shank when the lower one is in the ground; it thus becomes a non-fouling anchor and very compact for stowing.

I would be greatly indebted to Flight Lieutenant Cross if he would give us what he found to be the best proportions of anchors for the different sizes of flying boats.

I would also like to know if the author tried two smaller anchors instead of one, say one 40lbs. and one 35lbs., instead of one weighing 75lbs. In certain seas I found the two had better holding power. The author has not mentioned if he has tried tripping or scowing an anchor, and this I think is necessary when one has to anchor where the ground is known or suspected to be foul.

At present too many gadgets are stowed at the bow of flying boats, and I think it would be an advantage to stow the anchor away aft, even beyond the second step and for heaving at this position would be easier for the crew.

Referring to drogues, the tandem, as illustrated by the author (No. 3), is in my opinion much better than a single drogue, but here one must get the correct distance from first to second drogue, but this depends on the size of the boat. A floating anchor is another form of drogue and can serve the double purpose of enabling a boat to ride out in heavy gales in comparative ease.

Mr. ROBINSON, in a tribute to Flight Lieutenant Cross for the time and effort he had expended upon this problem, said he had seen him on the slipways at Felixstowe on cold, foggy, wintry mornings patiently measuring the loads that his last experimental anchor would take. Emphasising the importance of comfort in the cockpit, Mr. Robinson said that under present conditions, with a large open cockpit, spray was thrown up by the boat as she was taking off so that the pilot would get into the air for a long flight uncomfortably wet and with his goggles covered with spray. When in the air the pilot was subjected to cold draughts from every side, and in some instances found himself seated at a focus of sound from engines and propellers. A phenomenal advance had been made in the provision for the comfort of drivers of motor cars, and though an advance had certainly been made in this direction in aircraft construction, it was nothing like so marked, but it was nevertheless of first significance to the advance of flying.

Squadron Leader SCOTT disagreed with the author's suggestion that a dinghy was an unnecessary luxury.

During the recent Baltic cruise the dinghies which were carried by each flying boat were found most useful, and on one or two occasions they were an absolute necessity.

On one occasion the " Iris " landed near a small town in order to carry out repairs to an oil cooler.

The people of this town had taken no interest in them at first and had left them severely alone, and he did not know how they would have got the oil cooler ashore for repair if it had not been for the dinghy they had with them.

If the pilot of a flying boat were closed in altogether, difficulties would arise through impaired visibility when flying in rain.

A good all round view was essential, especially in bad weather, and to ensure this a very large number of windscreen wipers would be necessary.

With a closed in pilot's cockpit it would be difficult to give the pilot a good view behind the machine, and this was very desirable, especially when flying in company with other aircraft.

Captain SAYERS said he was particularly interested in the Short anchor with the abnormal holding power. Looking at it on general principles, it scarcely seemed possible that the anchor could have a holding power which was expressed in terms of its own weight. After all, it would require a certain amount of

weight to sink it, and no doubt its weight had some influence on the sinkage, but having got it down, holding power must bear some apparent ratio to the embedded surface, and therefore the lighter the anchor the greater the holding power should be. As the Short anchor was the lightest of those mentioned in the paper, he presumed that was the explanation of the high holding power. He would be interested to know if there were any other. Captain Sayers was painfully surprised at the author's estimate of the size of the crew for the flying boat of the future; presumably the author had in mind flights under Service conditions only and not under commercial conditions, for if a commercial flying boat were going to require a crew of ten when used for Empire communications we might as well give up straight away.

Mr. LANKESTER PARKER, discussing mooring apparatus, said he considered that to have a wire rubbing the side of the hull continually while in flight, as is the case with the present mooring arrangements, was a perfect nuisance. That was the only point on which he disagreed with the author.

Referring to Squadron Leader England's remarks as to bilge pumps, he said the difficulty was to decide with what sized leak the pump should be able to contend. In his own experience, whenever he had been unfortunate enough to hole the bottom of a flying boat the damage was too extensive for any reasonable sized pump to cope with, and the safety of the ship rested on its watertight compartments. Nevertheless, he agreed that an effective bilge pump is a great necessity, specially one that is not readily put out of action by dirt or articles such as an odd rivet.

Wing Commander MAYCOCK referred to the paper as most helpful and constructive and agreed with the author that it is very important at the present stage of flying boat development for designers to give a great deal of attention to improving the major items of equipment mentioned in the paper. The perfection of each item would go a long way to facilitate the maintenance and operation of the flying boats and increase their mobility and usefulness. In his opinion a stage in design and construction had been reached with which we should be very satisfied in that the performance now attained is practically equivalent to that of land machines of similar type, and this advance had been made within the last three or four years in spite of the fact that designers had to contend in their calculations with the vagaries of an entirely different element.

Having reached this stage, it is most important to get every possible use out of them to increase their popularity—of which he was confident—and to gain further information.

He believed that everyone with knowledge realised that flying boats had come to stay, and that in future they would progress at even a greater rate than in the past and take a place in world aviation as great or greater than that of land machines. This progress would be seriously hindered if the difficulties enumerated in the paper are not properly tackled now

It is most important that no one should be able to say that a flying boat would be at the mercy of the sea if forced to descend, or that they cannot carry a suitable anchor or dinghy. He was convinced that a serviceable anchor and dinghy should be carried, any way until the urgent need for them disappeared. That they are required now is evidenced by the help they afforded on the recent Baltic cruise.

He agreed with Squadron Leader England as to the value of the automatic pilot and thought it would take the place of the second pilot, especially in commercial aircraft.

(*Contributed.*)—I suggest that the quickest way to a solution of these problems is for two or three of our enterprising contractors to acquire one of the latest types and spend their hard earned summer holiday cruising round the British Isles and combine a very interesting business with doubtful pleasure whilst obtaining first hand information. Before undertaking a second cruise we

can be sure they would have found "ways and means" of providing really efficient equipment. One feels at present that perhaps they look on anchors, dinghys, moorings, re-fuelling apparatus, and the like as of very third rate importance and at the same time rather outside their sphere, but unfortunately we must rely on them to produce these items of equipment as they form part and parcel of the aircraft.

Reply to Discussion

Flight Lieutenant Cross briefly replied to the discussion. Captain Sayers had put forward the right solution to the problem as to why the Short anchor had had the greatest holding factor. The anchor was built to scale and the size increased, and precisely what was expected had happened, namely, the efficiency had fallen off so rapidly that it was not worth going further after the weight had been increased by about four times. He was much interested in the very constructive criticism of Wing Commander Cave-Browne-Cave, and the suggestion to use a chain specially designed for the purpose. It was perfectly obvious, of course, that any existing chain which was strong enough was hopelessly too heavy. He had expected that the designers would be up in arms when it was suggested that the anchor should be carried outside the hull, and he would be happy to hear of a better solution of the problem. He did not consider that the problem would be solved by carrying the anchor aft. Unfortunately, all the stockless anchors tried were found to be hopelessly inefficient, but he would be happy to hear of other stockless anchors which he could test. In thanking all those who had discussed the problem of anchors with him at Felixstowe and had helped him with their suggestions, he said Captain Nicholson had suggested the lengthening of the shank. The more one worked with anchors the less one knew about them, and to be dogmatic was to court disaster. He would hesitate very much to say definitely that certain dimensions were the best. With regard to the size of the crew, he pointed out that if flying boats had to use all sorts of harbours which were not permanent bases and not prepared as such, and where skilled assistance could not be expected, a large crew would be necessary, but if they were working between regular bases at which skilled assistance was available the number of the crew could be reduced. The large crew was necessary not so much for the work which had to be done while flying, but for the work to be done while on the water. It would be useless to have a flying boat which would fly for twenty hours and would then have to be held up for three days before it could proceed further. By increasing the number of the crew, and utilising the crew in a sensible manner, he believed that six hours' rest between flying periods of twenty hours—he was talking of the future, of course—should be sufficient. He agreed that the automatic pilot would be of great assistance, but could not see how the boats could be operated with less officers as the result of its use; he could not see how one officer and an automatic pilot could keep a service going, day in and day out, if that officer were to retain his good health. The boats would have to be run much as ships were run, *i.e.*, the crew would have to keep various watches. He did not suggest for a moment, however, that a commercial aircraft working between two points should carry a crew of ten; where there were bases at each end of the journey there was little necessity to carry more than one engineer.

PROCEEDINGS

Twelfth Meeting, Second Half, 63rd Session

At a meeting of the Royal Aeronautical Society, held in the rooms of the Royal Society of Arts, John Street, Adelphi, London, on Friday, June 1st, 1928, Flight-Lieutenant R. R. Bentley lectured on some technical aspects of his flight from England to Cape Town and back again in 1927 and 1928. The President of the Society (Colonel The Master of Sempill) was in the chair.

The President, introducing Flight-Lieutenant Bentley, said that he had originally come to this country with the Canadians at the commencement of the war, had joined the old Royal Flying Corps which later had been merged into the Royal Air Force, and had served until after the war. Then he had gone to South Africa, where he had given up aviation for a few years, having been engaged in railway work. In 1923, or about that time, he had joined the South African Air Force as an instructor, and had served with that force for a number of years. In 1927 he had returned to this country, and, having obtained support from certain newspapers in South Africa, had bought a Moth machine, and had made his very fine solo flight to the Cape, which had earned for him the Britannia Challenge Trophy, which was presented by the Royal Aero Club for the most meritorious performance in each year. That had been presented to him a few days previously. In 1928, having taken unto himself a wife—whom the members of the Society were glad to welcome at the meeting that evening—he had flown back to this country, with his wife as passenger.

SOME TECHNICAL ASPECTS OF THE FLIGHT TO AND FROM CAPE TOWN

BY FLIGHT-LIEUTENANT R. R. BENTLEY.

Perhaps I had better begin my story by giving you a very brief résumé of my flight outwards to Cape Town. The flight was made possible by the very enterprising support of the Argus South African Newspapers, who purchased the Moth for me. When the flight was completed the machine was given to me; hence the possibility of my returning, in a purely private sense, as I have done this year.

I started from Stag Lane Aerodrome, Edgware, on September 1st, 1927, and reached Cape Town on the 28th of the same month, the total flying time for the outward journey being 121 hours 45 minutes. The flight outwards was rather devoid of any particular incident worthy of note, but nevertheless it was an extremely interesting adventure to me. I had absolutely no engine trouble, and I always made my destination each day. There were no alarming adventures due to forced landings among wild people or in wild places. The fact that I was able to carry on without trouble speaks very well for, and is a tribute to, all the English producers who have a hand in the production of the Moth machine.

If I tell you the story of the flight back from Cape Town to England it will practically cover the flight in both directions, and I think the return flight holds a great deal more interest than the outward flight.

The flight to England came about in this way. My wife and myself were married on February 18th of this year, and we had decided to have a flying honeymoon to Victoria Falls. In the meantime Lady Heath, who was then in South Africa, and who has recently arrived in this country in her aeroplane, wrote to me to the effect that she was desirous of making a flight from the Cape to Cairo, and asking if I could help her with any information. I arranged that I should escort her over the forest belt. It was my intention to part with my wife at Broken Hill, proceed with Lady Heath to Tabora *via* Livingstone, and to return *via* Salisbury to Broken Hill to pick up my wife again. When we reached Broken Hill, however, everything was going so very nicely that I had a sudden impulse, and I suggested taking a chance for England. And here we are, having reached here on the same machine, with the same engine, that took me to the Cape.

We left Pretoria on February 20th. We flew first to Palapye Road, a distance of 240 miles, in 3 hours and 30 minutes. The going was good until we reached Limpopo, when it became very bumpy. We stayed the night at Palapye Road. There is an excellent aerodrome there, which had just been put into condition for the southward flight of the R.A.F. this year.

On February 21st we went to Bulawayo, a distance of 170 miles. There was a bit of a wind against us, and the journey occupied three hours. At the aerodrome there was only one long stretch of land, running north and south, which was fit to land on, and when we left, two days later, when there was a strong wind blowing from the east, we had to take off across the wind. The altitude at Bulawayo is 3,000 odd feet, but that seemed in no way to affect the performance of the machine.

On February 23rd we left for Livingstone, a distance of 242 miles, the time taken being 3 hours 45 minutes. On the way to Livingstone there is a length of railway line lying dead on the course for a distance of 87 miles, and that is very comforting when there is good visibility, which is a thing experienced more often than not in Africa. After leaving this railway line one passes over purely forest country, or almost purely forest country, and one has the comfort of being able to look back at this long stretch of railway and to take a tail bearing. The spray from the Victoria Falls sometimes rises to a height of about 1,000 feet, and it can be seen for a distance of about 30 miles on a day of good visibility. We stayed about a week at Victoria Falls. Incidentally, I met Major Cochrane Patrick, who had just completed an aerial survey of Livingstone and district, and his mechanics gave me every assistance. I took about eighty people up for joy rides over the Falls, the journey from Livingstone, across the Falls and back to Livingstone, occupying about ten minutes.

On March 1st we left for Broken Hill, a distance of 304 miles, the time being 5 hours 15 minutes. The flight to the south stood me in good stead on the return flight, because all the way back I was meeting people whom I had met on the way out, and they were all extremely kind to us both. We were delayed there a couple of days, owing to Lady Heath's machine having to be repaired, and on March 4th we carried on to N'Dola, a distance of about 110 miles, which occupied 1 hour and 10 minutes. We stayed there overnight, and went on to Abercorn on March 5th. We passed over Lake Bangwelo, about 150 miles out of N'Dola. The lake has a long island running across the centre, and absolutely parallel to our course, and it is a very comforting thing to be able to fly over that island, because it is a good area on which to land if necessary. On the south of the lake there is nothing but swampy country, full of lions and mosquitoes, so that it is not a pleasant place in which to reside for any protracted period. The distance from N'Dola to Abercorn is 342 miles, and the time was 5 hours 30 minutes. When we arrived over Abercorn there was a heavy rainstorm, and we had to fly around for ten minutes until it had passed on. The aerodrome there is about

the regulation size, having T-shaped legs or arms about 600 yards in length. There are none on the South African route which are smaller than 600 x 600 yards.

On March 7th we went on to Tabora, a distance of 280 miles, the time occupied being 4 hours and 30 minutes. We had to travel over forest country. When leaving Abercorn we had to go over a range of mountains rising to a height of some 8,000 feet above sea level, which means that we had to climb about 4,000 feet after leaving Abercorn. They are not nice mountains to cross, because if there is anything of a wind blowing you experience peculiar down currents. On the north side the range drops away over a very steep escarpment of about 3,000 feet. Coming from the south side, one has to go over a ridge before reaching the escarpment. As we flew over I felt the machine going down, and although I pushed the engine full open, the machine still continued to go down. That was not due to altitude or heat, but was simply due to a down current, which affected both machines in the same way. I had to steer for a gap in the ridge, and came over the escarpment that way. After passing over the mountainous country we travelled over purely forest country for the remainder of the distance to Tabora. The area over which we passed is entirely depopulated, owing to the prevalence of the tsetse fly and sleepy sickness. We reached Tabora all right, and found the aerodrome in good condition. It is a very fine all-weather aerodrome. It is very reassuring to know that as soon as one lands in East Africa the local defence force, which at that place is the King's African Rifles, immediately trot out a guard for the machine.

On the following day, March 8th, we carried on to Mwanza, a distance of 210 miles, covered in 2 hours 30 minutes. The aerodrome there was in good condition. At Tabora my escort duty had finished. My wife contracted a slight illness there, and the doctor said she should not fly for at least another two days, so we were delayed for two days to allow my wife time to recuperate.

On March 14th we flew to Nairobi, a distance of 325 miles, the time occupied being 4 hours and 30 minutes. The country there was hilly, and there were forests and open plains. Just before reaching Nairobi one passes over the Rift Valley, which would be a nasty place to land in. It has a series of ridges running along the bottom in a more or less northerly and southerly direction.

We remained in Nairobi from March 14th to 23rd, and on the latter date we carried on to Kisumu and Jinja, the total distance being about 312 miles, and the time 4 hours 15 minutes. That evening at Jinja, when I was examining my engine, I discovered steel filings in the oil, the presence of these filings being due to the dowel pins in the fork end of the connecting rod scraping the crank pins. I immediately decided to dismantle the engine and examine it thoroughly, and I soon located the trouble. Fortunately for me there was an old R.F.C. mechanic at Jinja, who refitted the bearings.

We left Jinja on March 28th, but when I was about half an hour out of Jinja the oil pressure went down. I had in mind that the engine had been dismantled and examined under rather unfortunate conditions. The garage in which the work was done was not as clean as one would like an engineering shop to be, and as everybody with experience of the dismantling and reassembling of engines will appreciate, stray bits of fluff and an odd hair or two will get in. Consequently, when the oil pressure went down to the minimum of 5 lbs. I decided, as two big end bearings had been refitted and had been given rather a neat fit, that I would not attempt the journey of 350 miles to Mongalla. Therefore, I turned back. When I got back to Jinja I found that the drop in the oil pressure was not due to the thinness of a purely mineral oil in a high temperature, as some people might have thought, but was due to a certain amount of dirt having got into the relief valve. As soon as I had cleaned that out and had run the engine up again, the oil pressure was perfectly satisfactory, so that on the following day, March 29th, we set out again for Mongalla. When we got to Nimule I lost sight of

Lady Heath, and began to wonder what had become of her. She had been flying about 1,000 or 2,000 feet above me, and unfortunately just in the sun, so that it was difficult for me to see. We had reached a point about half an hour's journey north of Nimule, which is 240 miles from Jinja, and not having seen Lady Heath's machine for five minutes or so, I became extremely anxious. Therefore, I decided to return to Nimule and to inquire there whether anyone had seen more than one machine pass over the town. When I landed there I found Lady Heath was not there, and was told that only one machine had been seen to cross the town. After taking in another four gallons of petrol, to make sure that there would be sufficient to take us to Mongalla, I flew back over the course for about half an hour from Nimule, in a southerly direction, and searched. Being unable to find any signs of a machine, I turned back again to the north and finally reached Mongalla, after a total flying time that day of six hours. To my relief, I found that Lady Heath had arrived safely.

On March 30th we carried on to Malakal, a distance of a little over 300 miles, which we covered in 3 hours 45 minutes. There we filled up and carried on to Kosti, another 250 miles, which we covered in 3 hours 20 minutes. We had hoped to reach Khartoum that day, but an unfavourable wind, coupled with the fact that we were delayed, waiting for oil, at Malakal, prevented that.

On March 31st we reached Khartoum, after a flight of 2 hours 30 minutes, the distance being about 160 miles from Kosti. On April 1st Lady Bailey landed in Khartoum. I had agreed to help her out by taking her across the Sudan; otherwise she would not have been allowed to carry on her flight to the south. The Sudan Government officials were exceedingly helpful and polite. As a matter of fact, I think this attitude on the part of the Sudan Government is not one which should be regarded as a cause for annoyance. The Sudan Government are the only people who bother about the safety of aviators crossing their country, and the area between Malakal and Mongalla, where they recently had trouble with the inhabitants, would be a definitely bad place for a lone aviator to land in. How the natives would take the landing is a matter of some doubt. They might run, but on the other hand they might not. The Sudan Government feel it incumbent upon them to take precautions for the safety of aviators passing over their country, and although an accompanying machine might not be of much use to a machine which had forced landed at such a time, it might be able to pin-point the latter, indicate its position, and so facilitate the finding of it by the search party which the Sudan Government would send out. Naturally, the sending out of search parties involves considerable expenditure, and one can quite appreciate why the Government do not like people to fly alone over their territory.

I left for Kosti on April 5th, accompanying Lady Bailey. We reached Malakal on April 6th, Mongalla on April 7th, and Nimule (which is on the Sudan border) on April 8th. I did not land at Nimule, however, but waved good-bye to Lady Bailey and returned at once to Mongalla. On April 9th I returned to Malakal and went on to Kosti the same day, and on the 10th I went on to Khartoum. On April 12th we left for Atbara, the two days we had spent in Khartoum having been spent to a certain extent in reconditioning the machine; I had the wings dismounted, and the centre section trued up. We reached Atbara, a distance of 185 miles, in 2 hours 35 minutes. The headquarters of the Sudanese Government Railways are situated there, and one can get practically any aeroplane repair carried out. There is also the most wonderful natural aerodrome in the world, having an absolutely level surface of hard gravel.

On the following day, April 13th, we crossed to Wadi Haifa, a distance of 360 miles, which we covered in 4 hours 30 minutes. We were very careful to follow the railway line, because if we had to land in an area such as that, which was just desert, with nasty-looking hills sticking up out of it, it would be rather a thirsty business. On April 14th we went on to Luxor, a distance of about 245 miles, which we covered in 4 hours 45 minutes, and on the 15th we went on

from Luxor to Cairo, a distance of 360 miles, occupying 5 hours 50 minutes, following the Nile all the way. The Nile is a rather wonderful river, when one realises that about 40 million people depend upon it for life and sustenance.

Having reached Cairo—and, I suppose, what was more or less civilisation—our troubles commenced. Up to that time we had sailed merrily on, without passports, without tryptique. The people in central Africa did not care; they were out to help. As soon as we got to Cairo we commenced to strike snags, and I had to get passports and a tryptique. The French Consul was very kind, and he fixed the matter up in about two hours. Then I took the passport to the Italian Consulate to obtain a visa for Tripolitania, that nasty little piece of land along the North African coast, and we were held up for two weeks waiting for that visa.

We went on from Cairo to Abu Kir on April 21st, and at the latter place I gave the machine a top overhaul. The engine by that time was getting pretty old, for it had done about 350 hours' flying. I had ordered some spares in case I should need them, but unfortunately they had not arrived. The examination of the engine at Abu Kir by the R.A.F. mechanics at the time of the top overhaul, however, established that the engine was quite good enough to enable us to carry on without any replacements whatever.

On April 29th we left for Solloum, a distance of 295 miles, which we covered in four hours. We filled up there and carried on to Ben Ghazi on the same day, where I had to carry out a slight repair, made necessary by my clumsy handling of a spanner. A new rocker arm had to be fitted. At Ben Ghazi I tested the machine and took an Italian Air Force officer up with me, for the officers there had been very good to us. After flying around the aerodrome, trying a few vertical banks fairly close to the ground to show how handy the Moth was, I came down and shut off in about the centre of the aerodrome. The officers on the aerodrome prepared to run, but when the machine landed at about 35 m.p.h. and sat down and stayed, they were delighted.

On May 2nd we left for Syrt, round the Gulf of Sidra. Knowing that we were to cross the sea later, I did not want to cross the Gulf and to fly at a distance of anything up to 100 miles out at sea. Therefore, we went round the Gulf to Syrt, where we stayed the night at a good Italian Air Force station.

On May 3rd we went on from Syrt to Tripoli, a distance of 300 miles, occupying 5 hours 30 minutes. We were heading into a strong wind blowing along the coast; the visibility was poor, and the bumps were worse. I had been rather worried previously about crossing the Mediterranean, and although Lady Heath had very kindly offered to share her Italian escort with me, I felt that even Italian escorts were capable of losing their way between Tripoli and Malta. I decided, therefore, to go right round the coast as far as Tunis. On the following day (May 4th) we left Tripoli, and Lady Heath came with us. We landed at Sfax. That would not have been necessary but for the fact that I had left my map of Tunisia at the back of the machine, and it was necessary to land in order to get the map. We landed on a track of level sand, and after filling up we carried on to Tunis that day. Lady Heath, Captain Stack, Manning and ourselves were all in Tunis together, so that there were four light aeroplanes there.

On May 6th we left for Catania, in Sicily. The sea crossing was a distance of perhaps a little over 70 miles. The total distance from Tunis to Catania is about 300 miles, which we covered in 4 hours 15 minutes. It is a comforting thing, when half-way across the sea, to be able to see land both in front and behind—Africa at the back and Europe in front. We stayed the night at Catania and renewed old acquaintances, for the C.O. who was at the Italian Air Force station there when I flew south was there still.

On May 7th we left Catania and made a non-stop flight to Rome. On May 8th we left Rome, and I experienced the first forced landing with that

engine. The landing, however, was not due to faulty material in the engine; it was due to lack of sufficiently acute inspection on my part. A push rod had broken because the cup of the rocker arm was somewhat worn and had in consequence thrown a side strain on the head of the push rod. I landed in a field about ten kilometres north of Rome, between the hills, among some rather long grass, but quite near a main road. The rain began to pour down soon after I had landed, but I soon discovered the trouble and replaced the push rod and rocker arm. My wife stood out in the rain, handing up spanners and things. A number of motorists stopped and asked if I were all right, just as they would inquire of a motorist who had broken down, and when I replied that I was all right they passed on.

On May 10th we left for Nice, reaching there after a flight of five hours, and carried on to Marseilles the same day, a further flight of 1 hour 55 minutes. On May 11th we reached Lyons in three hours, filled up, and went on to Paris, the journey occupying another 3 hours 45 minutes. Then on May 12th we flew from Paris to Croydon in 3 hours 20 minutes, and from Croydon to Stag Lane, Edgware, in 15 minutes.

That completes the story of the homeward flight. Speaking of the flight generally, I might mention that Jinja is an excellent little town to stay in, and if anyone is doing the same flight at any time I should recommend him to stay there. There is plenty of shooting of all sorts, and the people there are very kindly.

So much for the flight and its technical aspects. The reason for it, as I have said, was purely that of adventure. There was no intention to make the flight in the first place, and in the second place there were practically no preparations made. But when, at Broken Hill, we decided to go on to England, I sent a cable to the Shell organisation at Cape Town. That organisation had been supplying me with petrol and oil up to that time, and I cabled to the effect that we were carrying on to England. They told me to carry on, but stated that I might have some little difficulty about supplies at certain points with regard to which they were not quite sure. I pushed on, however, and only at four places had I any difficulty about obtaining supplies of petrol and oil, in spite of the fact that I had made the journey through Africa at a moment's notice.

From Pretoria up to N'Dola one can rely on obtaining normal supplies of motor spirit and Shell motor oil. It is only when one gets to Abercorn that it will be necessary—or, at least, in the past it has been necessary—to have special supplies laid down. Abercorn is at the foot of Lake Tanganyika. There is a railway running up from Cape Town and passing through Bulawayo, Livingstone, Broken Hill and N'Dola, on the Congo border, so that one can rely on supplies at any time there. The aerodromes, with the exception of that at N'Dola, are fit to land on at any time of the year, but at N'Dola during certain months of the year—I should say between February and October—the grass grows very long, due to the heavy rainfall, and it is necessary to cut it. The aerodrome site covers an area of about 750 × 750 yards, and there is nothing to worry about from that point of view. Supplies for Abercorn are generally brought down the lake by steamer, but I understand that the Shell people are keeping supplies of petrol and oil there always in future for the benefit of itinerant aviators. Mwanza is at the southern end of Lake Victoria Nyanza, and a railway, if it has not already been opened, will shortly be opened to Tabora, but in any case standard supplies —Shell petrol, Shell oil, Mobil oil—are always there. Kisumu is a railhead, and there, as at Nairobi, one can get anything and everything. The aerodrome at Kisumu is perfectly good. At Nairobi the aerodrome has an undulating surface, and the effect of the altitude—6,000 feet—is felt. At Mongalla special supplies will have to be laid down. The only petrol and oil available there is that of the Sudanese Government, and the Sudanese Government petrol contains a red dye which is rather nasty for carburettors. The same remarks apply at Malakal and

Kosti with regard to supplies. During the rainy season, which lasts from early in May until September, the conditions for crossing the Sudan are definitely bad, because after a good shower of rain the aerodromes become bogs, and even a light aeroplane will sink in up to the axles. At Khartoum there is an R.A.F. station, and all supplies are available there. At Atbara, too, supplies are always available. At Wadi Haifa petrol can be obtained, but not oil. For the rest of the journey up the Nile to Cairo no trouble is experienced with regard to supplies, but supplies have to be put down at Solloum. Supplies can be obtained at any time at Ben Ghazi. At Syrt I was given Shell petrol by the Italian Air Force. At Tripoli supplies can be obtained at any time. At Syrt the Italian organisation has control of fuel supplies, and there is the same organisation up to Tunis. In Europe, of course, the matter of supplies becomes absolutely simple. Altogether, it will be seen that in the matter of supplies this South African flight is not difficult.

With regard to cost, the average price of petrol all the way through would be about 3/- per gallon, and the average price of mineral oil about 9/- per gallon. In some places one has to pay nearly as much as 6/- per gallon for petrol, but in other parts it is as low as about 1/6. For the information of anyone who might be contemplating such a flight, I should say that it would probably cost about £100 for petrol and oil. That is based on a total flying time of 125 hours, a petrol consumption of about 4¼ gallons per hour, and an average oil consumption of about 1¼ pints per hour.

The engine spares I carried consisted of two sets of valve springs, two valves (one inlet and one exhaust), two rocker arms, two push rods, one float, one set of float counterweights, one needle valve for controlling altitude (the carburettor is a Hobson), and two rocker arm fulcrum brackets. There were also some spare K.L.G. plugs. So far as the machine itself is concerned, I had two spare tubes, fabric, dope, dope solvent, needles, thread, and all the usual necessary things, such as wires, split pins, spring washers, etc.

Coming to the repairs which had to be carried out on the journey, at Jinja the big ends had to be looked at. At Abu Kir there was a top overhaul. At Ben Ghazi I fitted a new rocker arm fulcrum bracket. Then at Rome, on the occasion of the forced landing, a new rocker arm and push rod had to be fitted. On the whole, the behaviour of the engine was very fine indeed. There was no appreciable loss of power with altitude—not sufficient to make the machine feel bad about it. With regard to taking off at high aerodromes, the highest aerodrome under tropical conditions was at Nairobi, which is very close to the equator. There the matter of getting off with full load was noticeable, but it was nothing to be alarmed about, and throughout the flight, in the high parts, at an average height of 4,000 feet, the machine always left the ground when about half-way across the aerodrome, so that there was always about 300 yards to spare.

Coming now to the repairs to the machine itself, at Khartoum the wings were dismounted and the centre section trued up. At Catania the forward bolts in the tail plane were tightened. No overheating was experienced. The oil pressure was always constant, except when foreign bodies got into the relief valve; then the pressure went down with a drop. That happened only once. It was not possible to tell what the temperature was, and one did not bother about it, because the oil pressure was always good. With regard to transport and the problem of getting supplies of fuel and oil to the aerodromes, there were only three places on the route at which I found it necessary to pay for transport, *i.e.*, Mwanza, Luxor and Tripoli. At all other places the people brought the supplies out. Emergency communications are quite all right in Rhodesia and Northern Rhodesia, they are fair in the Sudan, indifferent in Uganda, Kenya and Tanganyika, and bad at Abercorn, which is situated in the northernmost part of Northern Rhodesia. It would be difficult to get messages through if one came down anywhere there. They are good from N'Dola to the Cape. One

would like to see rest-houses put up at the various aerodromes in the Sudan, because it falls rather heavy on the very willing people who receive us at those places to have one " parked " on them at their expense.

The best times of the year for such a flight are either when the R.A.F. carry out their flights, *i.e.*, in March, April and May, or in September and October. The best weather is experienced during these times of the year. It is difficult for me to say what is the best route. I have not studied the matter from the point of view of the seaplane or flying boat, but the best land route, I should say, was the one I followed, with a slight modification going south from Nairobi. The aerodromes are positioned very well, the average distance between them being from 300 to 350 miles.

The machine I used was a D.H.60 x Moth, with a Cirrus, Mark II., 75 h.p. engine. Its estimated weight, fully loaded, was 1,550 lbs., the petrol capacity being 31 gallons (19 gallons of which were carried in the centre section tank) and the oil capacity being two gallons in the sump.

Discussion

The President said it would be agreed by all that the value of flights such as that which had been described so modestly by Flight-Lieut. Bentley was immense, because such flights would become more and more common, and the experience of Flight-Lieut. Bentley would be of very great advantage to those who contemplated flights of a similar nature, as well as to the designers of the aircraft and the engines. One of the most interesting aspects of the flight was that it showed clearly what a passenger could endure. Mrs. Bentley, who had hardly flown at all previously, had set out, apparently without a thought of the difficulties, and had flown from South Africa to this country in considerable comfort. Those who were pilots would admit that the passenger's part in a journey of that kind was by far the harder and more unpleasant, because the passenger had to sit in a small cockpit, cramped up, with all the spares and tins of one kind and another. There was no doubt that Flight-Lieut. Bentley had by far the more pleasant part of the trip. He would like to know the lecturer's opinion of the ideal light aeroplane to suit the particular conditions he had met, and in what respects the ideal machine would differ from the machine he had used. It would also be interesting to know what daily inspections were carried out, and whether Flight-Lieut. Bentley had found that those inspections were absolutely necessary at such frequent intervals. Again, had he used a wooden propeller, and had he used more than one throughout the trip?

Squadron-Leader Slatter referred to the problem of navigation, and asked if Flight-Lieut. Bentley had had any trouble in picking up his land marks, and how he had picked them up. Had he relied entirely upon the compass, or were his maps sufficiently accurate to enable him to identify the various parts of the route?

Mr. Chorlton said that he looked at this flight in the broad sense, as it would probably appeal to the ordinary engineer, and he had been impressed by the necessity for exercising great care in looking after the power plant throughout the trip. He asked to what degree one could count upon an aeroplane engine functioning as a motor car engine functions at the present time. It might be said that this depended partly upon the rating of the engine, for a motor car engine ran at a low rating, whereas the engine used on the Moth machine, although not rated very high, was rated a good deal higher than a motor car engine. On the other hand, the possibility of a tappet coming out had not much to do with the rating; that would depend more on the piston, the rings, and the cylinder itself. Given that one was an extraordinarily careful man and that one examined the machinery carefully on landing and before taking off again—and he had noticed that Flight-Lieut. Bentley had not taken chances, but had turned back when in

doubt—one had a good chance of getting through, and he could not help feeling that caution was the essential feature in the success of this flight. The percentage of people who took risks such as were involved in the Atlantic flight, and yet won through, would be very small. It was an immense satisfaction, however, to know that flying was developing with us individually. This country had developed and grown and had become what it is through the strength of individuals, and it was very comforting to think that, despite the wonderful results that had been obtained by the help of Government subsidies, we were making progress ourselves individually.

Mr. W. O. MANNING said he was impressed with the fact that it was possible, without any preparation whatever, to start out and navigate practically an entire continent with a mere pocketful of spares. Also, the confidence of the pilot in his machine was evidenced by the manner in which he had wandered about over forests of considerable extent, over a considerable expanse of sea, and so on, with considerably less trepidation than that with which some of the earlier aviators had crossed the Thames. There seemed to be no special difficulty. Somewhere he had seen it stated that South Africa was inhabited by a species of ant, which, when a machine had landed, attacked the woodwork of a machine. He would like to know if Lieutenant Bentley experienced any difficulty with these ants. Had Flight-Lieut. Bentley had any difficulty with the rubber parts of the machine—the rubber shock absorbers, tyres, and so on. He believed that on certain aerodromes in Africa there was considerable difficulty due to the presence of a rather long species of thorn, which punctured the tyres. Again, had there been any trouble due to the shrinkage of the timber of the machine, because it had flown from a humid to a drier climate; did any of the fittings become loose?

Captain H. M. SAYERS said that, so far as he knew, no pilot who had flown over the African route had stated definitely how much of it was of such a character that if one had a forced landing one would have a chance of emerging. It would appear that many parts of it were such that if one had a forced landing one would never be heard of again, and he asked to what extent did the route cover country of that sort, and to what extent did it cover reasonable territory. The singular success which had attended the various flights which had been made over this route would suggest that Africa must be very nearly an ideal country for flying, and he asked to what extent that was true.

Captain C. C. WALKER said that an interesting point which had been brought out by this flight was the apparent ease of flying under conditions which should, theoretically, be extremely difficult. With a total weight of about 1550 lbs., and a horse-power of about 80 at ground level, there appeared to be no difficulty worth talking about in flying from aerodromes situated about 4,000 ft. above sea level in a temperature of 100 deg. F. It would appear that that was hardly a flying proposition at all, but the experience on this flight and on other flights, in Australia and other parts of the world, indicated that the problem should be looked at in a different manner from that in which it was generally looked at; the engine must be regarded as giving more power than it was generally credited with under conditions of altitude coupled with a high temperature, and if Flight-Lieut. Bentley could compare the conditions here with those existing in Africa his information would be valuable.

Colonel DARBY, who pointed to the fact that the stages between the aerodromes were comparatively short, and that most of the flying had been done in the early hours of the day, asked Flight-Lieut. Bentley whether he would anticipate other and greater difficulties if the stages were longer and if he had flown at any time of the day, when the temperature was a good deal higher than in the early morning.

Captain E. G. WALKER, asking for more information with regard to routine inspection, said that it would be extremely valuable both to the designers of aeroplanes and engines and to the pilots. It was extraordinary, he said, how

much ground could be covered at a small cost, although, of course, the various suppliers of fuel etc., such as the Shell Company, were prepared to aid pilots. It was apparent that in a very short time we should have routes such as this blazed out, with full facilities for obtaining supplies of fuel, spares, etc. He asked Flight-Lieut. Bentley what engine power he considered the light aeroplane should have.

Colonel FELL asked what was the normal throttle position adopted on flights of this kind. That was important because the life of the engine depended upon its rating. The performance of the engine used by Flight-Lieut. Bentley seemed to have been excellent. It was a very simple type of engine, and, of course, had had the very best possible work put into it, but it was important to know exactly what loading it was subjected to under normal conditions.

Flight-Lieutenant ALLEN asked if it had been found necessary to use any spares on the machine itself, as apart from the engine, during the flight. The only part of the Moth machine that he had broken was the spring of the tail skid, and he assumed, therefore, that that was the weakest part of the machine.

Mr. MOSTYN, dealing with the questions of throttle opening and the normal cruising speed which was found to be necessary, said one rather presumed that on these long flights there was a tendency to increase speed a little beyond what was normally considered to be the cruising speed, in order to make more headway. He did not know whether that was so or not, but he pointed out that the engine was tried out under very severe conditions, and asked to what point it could be pushed with safety. He also asked what oil it was desirable to use in tropical climates, and what the oil consumption was under tropical conditions.

Mr. SPRY asked what rations were carried in the machine for consumption in the event of a forced landing at a place where it would be difficult to obtain supplies.

A SPEAKER suggested that Flight-Lieutenant Bentley's achievement might lead other pilots to attempt somewhat similar flights, and he asked if Flight-Lieutenant Bentley considered that such flights should not be undertaken by people having less experience than himself.

The PRESIDENT, discussing the question of the attack of the woodwork of aeroplanes by ants, recalled that in the early phases of the war in East Africa, when the machines of the day were sent out and operated by the R.N.A.S., a great deal of difficulty was experienced due to the attacks made by a certain species of white ant. The difficulty was met by standing the tail skid and the two wheels of the machine in the middle of baths of kerosene, so isolating the machine and preventing the ants from getting to it.

REPLY TO DISCUSSION

Flight-Lieutenant BENTLEY, replying to the discussion, said that in his opinion the ideal machine for such a journey as he had described would not vary greatly from the machine he had used. The type of machine he had used was very satisfactory indeed, all things considered, but there were one or two points about the construction which might be altered. For instance, there should be a more comfortable seat for the passenger. Also, the fuselage of the machine should be covered entirely with fabric. The fabric should be glued on to the three-ply before it was painted, and his machine provided striking evidence of that. The back of the Moth, which was fabric covered, had withstood all the stresses imposed by varying temperatures, strong sun, rain, and so on, but on the sides of the fuselage, which were not so treated, the top surface of the three-ply had cracked —not seriously, but more than it ought to in aircraft. That could be definitely remedied, he believed, by covering the three-ply with glued-on fabric.

With regard to controls, he said that wherever there was any friction between them and other objects he had had them covered with copper. That was done by using a strip of copper, the width of which was equal to the circumference of

the control wire, and clipping it round the wire for a distance of about eight inches. That was sufficient to cope with any friction due to the movement of the control past an object with which it came into contact. The controls on the machine at the present time were those which he had used on his flight southward.

With regard to the daily inspections, he said the first thing he did was to pull out the oil filter and examine it for signs of metal of any description. It was that practice which had saved him from trouble after leaving Jinja, for it was there that he had detected the presence of steel filings. Next, the petrol filter was examined. It was very seldom that he found that in a condition which would jeopardise the certainty of the petrol flow, however, because the petrol was always put through a chamois leather funnel when the tank was filled. Next, he examined and cleaned all contact breakers, examined the bolts which held down the engine to the engine mounting, then examined all rocker gear and valve springs, and lubricated all the valve stems with Dixon's graphite and grease by means of a specially constructed gun to pass between the springs and partially encircle the valve stems. Incidentally, the valves now on the machine were the valves used on the southward flight. The rocker gear was also lubricated with a mixture of graphite and grease. The K.L.G. plugs were changed once every ten hours. He had carried a spare set, and the set which was not in use was cleaned at leisure, but was ready to replace the set in use at the end of ten hours. He had flown to the Cape and back on the same two sets of plugs—K.L.G. S 15's. The tightness of the propeller on the boss was also examined each day, and the valve clearances were adjusted.

The propeller used for the outward flight was still on the machine. A practice adopted in South Africa was to enamel the propellers with Ripolin enamel, balance them, and then paint the back faces a dead black, so that they would not dazzle the eyes of the pilot. On arrival in South Africa he had had both propellers—the one used and the spare one—tested for pitch, and had found that the propeller used on the machine was in better condition than the spare; it had lost no pitch at all.

With regard to navigation, he said the route was not at all a difficult one. The route across France and down the Italian coast was quite easy to follow. The route he would use in future would be *via* Tunis. The sea journey was only 70 miles, and it was quite easy to follow provided one took drift observations before leaving the land. There were two large places to aim for, depending on whether one was flying towards Africa or towards Sicily, so that it was not difficult to steer a fairly accurate compass course. He had developed what he called the "drift" sense, *i.e.*, it was his practice to lean his cheek against the side of the fuselage and watch a particular object, and observe in what position it passed out from under the leading edge and under the trailing edge of the machine. From that he was able to calculate the drift, and make the necessary allowance on the compass.

As to the examination of the machine itself, he said there was very little to do. Only on one occasion, *i.e.*, when he had arrived at Pretoria after the flight, had the bolts to be tightened, apart from the occasion at Catania, when he had detected a certain amount of looseness in the planes.

The ant which did the damage in Africa was the termite, or white ant. This ant, however, did not like the daylight. When working, it built a tunnel of dirt in front of it, and never came out into the daylight. If it attacked an aeroplane, one could detect its operations owing to the presence of the little tunnels of earth which it would construct wherever it was working. It would not travel over steel, of which the tail skid was composed, because earth would not stick to steel easily. Also, it did not like travelling over rubber. In any case these white ants had not bothered him, and he had not taken particular precautions against them.

Replying to Mr. Manning, he said the rubber shock absorbers seemed to be still as resilient as they were when the machine was new, and the two tyre covers used on the outward flight were still on the machine. He had had two punctures in the course of the 394 hours during which the machine had been flying. The thorns which Mr. Manning had mentioned existed in Central Africa, but they were not in evidence on the aerodromes. Past experience had taught us that the aerodromes must be kept clear of them. There had been no trouble due to shrinkage, except in the isolated case he had referred to. The compression struts inside the wing construction, being of steel, did not shrink, and at the end of his outward flight the planes were examined and found to be in excellent condition. Not a wire had to be touched.

One part of the journey which was dangerous was between N'Dola and Tabora, a distance of 550 miles or more. Another dangerous stretch was between Malakal and Mongalla, a distance of about 300 miles. There one left the telegraph line and kept to the east of the White Nile. One had to fly over the newer country there, and the lines of communication were bad; indeed, they were almost non-existent. But there, one was in the Sudan, where telegraphic communications were good, so that the time at which the machine left one aerodrome would be known and the time required to cover the distance would be allowed for, and the non-arrival of the machine would cause alarm. A search party would then be sent out. The total distance which was dangerous over the whole route was a distance of about 1,000 miles. Perhaps, also, it would be unsafe between Ben Ghazi and Syrt, on the north African coast, where there were many Arabs; the distance between those two towns was about 300 miles. There was wireless communication between the stations there, and in the event of the non-arrival of a machine the Italians would send out armoured cars, he believed.

Dealing with the question of temperature, he said that when flying through Africa it was always advisable to get off as early as possible each morning, attain an altitude at which the air was cool, and stay there for the period of the flight. If one descended to a lower altitude, bumps were encountered, and it was very difficult to get up again through the hot air. During the flight to England they had left Malakal for Kosti at about ten o'clock, and had encountered some of the worst bumps he had ever experienced. They would climb to about 3,000 feet, after a struggle, and then encounter a bump and lose about 2,000 feet. If one started early each morning one need not worry as to the take-off and the performance of the machine in the air. It was rather difficult to make a comparison as between the performance of the Moth in this country and in Africa. If, however, one flew a Moth at sea level, carrying the normal amount of petrol (19 gallons) and no spares or tools, and then flew it again at sea level when loaded to a total weight of 1,550 lbs., the difference would represent about the difference between flying at sea level and at altitude in a place such as Nairobi under constant conditions of loading.

During the whole of the flight the throttle was a little more than half-way open, no matter what the altitude. At sea level the Moth travelled at nearly 80 m.p.h., but at altitudes of about 8,000, 9,000 and 10,000 feet in the tropical heat during the day the cruising speed fell off to about 70 m.p.h. or a little lower. He had not opened the throttle, however, in order to pick up speed.

The tail skid spring which was fitted to the machine when he left England was still in use. With regard to oil, he said that on the homeward trip he had used mineral oil—Shell Golden—and at all temperatures the pressure was the same as that of a vegetable base oil. Furthermore, it did not stick up the top piston rings, as had been his experience in the past, and at all times it seemed to have sufficient viscosity to carry the engine through, even in the hottest parts. The consumption was from 1¼ to 1½ pints per hour, which was not so bad when one considered that the engine was getting old and the tappet guides were getting worn, so that quite an amount of oil was forced out through the tappet

guides. There had been no need for an auxiliary oil tank. An auxiliary tank, to augment the capacity of the sump, was fitted to the machine for the outward journey, but he had never coupled it up. On arrival at Pretoria after the completion of the flight he had removed it, and he had never had occasion to use more oil than the normal two gallons, which was the capacity of the sump.

The rations carried consisted of dates, tongue, Oxo cubes, and other sustaining foods of that nature. A rifle was also carried, because one could always shoot food in Africa in the event of a forced landing. Matches were also necessary.

Dealing with the question as to whether pilots with less experience than himself should attempt such a flight, he said that pilots should have sufficient commonsense to allow for altitudes. If they had not considerable experience of flying at high altitudes and landing on high altitude aerodromes, they should cut out all stunt manœuvring near the ground. The best way to approach a high altitude aerodrome was by means of a straight glide and a sideslip, and if a pilot over-shot the mark he could open up the engine and run round again. It was his experience that when manœuvring near the ground at high altitude aerodromes it was necessary to increase the air speed by five or six miles per hour beyond the speed required at sea level, in order to ensure a decent margin of safety. He emphasised that private owners should make every effort to gain as much knowledge of their machines, and particularly their engines, as possible, because a certain number of failures were due to lack of knowledge. If British products were going to put up a good show in the world it was up to the owners to handle them properly, and he trusted that enthusiasts would see to it that they handled the machines as well as they could, and treated them fairly. Consideration for the engine undoubtedly meant a lot on a flight on which reliability was absolutely essential, and an engine would always respond favourably to proper treatment.

PROCEEDINGS

THIRTEENTH MEETING, SECOND HALF, 63RD SESSION

A meeting of the Royal Aeronautical Society was held in the rooms of the Royal Society of Arts, 18, John Street, Adelphi, London, on June 14th, when a paper by Sir Hubert Wilkins, on "Arctic Flights," was read. The President of the Society, Colonel the Master of Sempill, was in the chair.

The PRESIDENT said that the Society considered it a great privilege to extend a welcome to Sir Hubert Wilkins. Sir Hubert had that day had the honour of being received by H.M. the King, who had conferred a knighthood on him. Sir Hubert Wilkins learned to fly at Brooklands in 1910 and had had a varied and adventurous career. In the Balkan War he acted as Press correspondent with the Turkish forces. In 1914-18 War he held a commission in the Royal Australian Flying Corps, in which Service he gained considerable distinction. At the end of the war he started to fly to Australia, with a view to winning the £10,000 prize, which was subsequently won by Sir Ross and Sir Keith Smith.

ARCTIC FLIGHTS

BY CAPTAIN SIR G. H. WILKINS, M.C.

When Trans-Arctic transportation becomes common, when air routes take full advantage of great circle courses, when we travel from New York to New Guinea via Point Barrow, Alaska, from Chicago to China almost hitting the North Pole on the way, and from San Francisco to Moscow via Spitsbergen, then, and then only, will those concerned with aerial transportation realise the facilities the Arctic affords the aerial navigator.

It has been our privilege and pleasure, Eielson's and mine, to help establish Trans-Arctic transportation as an actual fact. We sincerely appreciate the honour of meeting you and welcome this opportunity to put before you some of the problems met, to explain how they were dealt with and to draw attention to the problems still to be overcome. The possibility of flying in the Arctic was first brought to my notice in 1913 when with Stefansson's Canadian Arctic Expedition. We had lost our ship and most of our food and equipment and yet Stefansson with great courage decided to carry on. He was convinced that his theory of living off the country while exploring was sound and wanted to prove it, and prove it he did. But the proof was long and arduous. I was brought up in the Australian Bush where horses were always at hand and where walking was considered an unnecessary means of locomotion. Unaccustomed to walking or to working, it was no wonder that when under the continuous sunshine and the calm air conditions of an Arctic spring and facing a tramp of a thousand miles over foot-clodding snow, my thoughts turned to some method other than dog team travel.

Many times I suggested to Stefansson that he should return, secure airplanes and pilots and cover in a day instead of a year the area in which he was interested. I believe the machines available in those early days of flight would have functioned in Arctic conditions. Their range was not far, but they could travel as far as any explorer carrying his own supplies might travel on foot, and there was

always the chance for the explorer by air to use his feet if his airplane should fail. The question of possible landing fields on the Arctic was of greatest importance. An airplane then, and even now, is ill-provided with means of taking off the ground and coming to rest. In most instances fields must be prepared before they are fit for an airplane to land on. But along the lagoon-fringed shore of the Alaskan Arctic there were hundreds of miles of ice as flat as a table. Throughout much of the year this ice was covered with a smooth surface of snow less than twelve inches deep. Having gained considerable experience with aircraft during the years between 1910 and 1913, I was able to look at a surface with a pilot's point of view, and day after day as I travelled along the Arctic shores and over the sea ice, my attention was drawn to many suitable landing fields. In summing up the conditions it was my estimate that near the Alaskan shore, both right next the land and on the sea, emergency landing fields would be found within a radius of twenty miles. In my mind the problem of landing fields was settled. I believe that more suitable emergency fields would be found on the pack ice than in most unsettled country districts.

Many engineers doubted that engines would function in the low temperatures experienced in high latitudes. From personal experience with internal combustion engines used on the Stefansson expedition, I knew that gasoline motors would not function if exposed to such temperatures as we would meet during an Arctic winter or spring. Many times during the spring and fall I had to resort to an oil stove placed right beneath the carburettor in order to keep that part of the engine free from ice. It required little inventiveness to arrange a convenience for heating the air before it entered the carburettor and it would be an easy matter by means of suitable cowling to insulate an airplane from the cold. I could see that problem number two would be easily solved. There was the question of lubrication. Provided the oil and the engine were warmed at the start, the other arrangements just as mentioned, then the heat generated by the engine at work would both heat the engine and the oil before starting. Metallurgists knew, but the average flying man did not know, that the low—not extreme temperatures—to which the engines and equipment would be submitted in the Arctic would not by the difference of coefficient of expansion seriously endanger the perfection of engine assembly, and in any case while it might have been inconvenient to arrange, it would be impossible to keep the engine always above freezing point. I had managed to do this for many days at a time when operating internal combustion motors in the Arctic. I found that when covered with a close-fitting canvas cover of double thickness, I could with an ordinary hurricane lantern keep a 100 horse-power gasoline engine warm while at rest even at temperatures ranging far below zero.

Experience taught me that if trouble was to be avoided it was necessary to use a double covering; one covering must be of some material neither wind-proof nor water-proof, the outer covering should be both water-proof and wind-proof. This arrangement was necessary in order that the warm air would condense not on the engine and ignition system, but on the outside of the inner cover and the inside of the outer cover, thus excluding the dampness from the engine. Therefore all the difficulties with the prime motive power could be overcome; the engine certainly would not work in the low temperatures, but it was easily and economically possible to protect the machinery from those low temperatures and create about it an air condition that was normal, in fact suit the condition to the engine, not the engine to the condition. Man has been doing this with regard to his body for many thousands of years; we do not suffer the cold if we are well dressed, we are protected from it. It was a question in some minds whether the wings and the fuselage of the plane would withstand polar conditions. All doubt about that was cleared by the evidence collected during Sir Douglas Mawson's expedition in 1912, when he used in the Antarctic in temperatures well below zero an airplane fuselage. It showed no ill-effect because

of the temperature conditions. With regard to the atmospheric actions—it needed little deep thought to show that if a square footage of wing surface under power in the tropics would support a machine in the air, it would certainly do so in the heavier, colder air in the polar regions. And so all other apparent difficulties with regard to equipment seemed to me to be solved. It was only a question of adaptation by human hands. When all was considered it was not a matter of whether the machinery could stand the gaff, it was whether the humans in control could accommodate themselves to the strange conditions. Some of us had been privileged to experience polar conditions and knew how really comfortable they could be, but this knowledge was gained only by experiencing in our early ignorance real hardships, and by learning gradually the ways of comfort. We learned also that the human mind can only fully comprehend that within the bounds of its own experience. We knew from our own experience that the job of flying in the Arctic could be done, nevertheless it was doubted by others, some with and some without experience. We might not do it successfully, because any man or machine is prone to fail, but it did not alter the fact that some day someone would prove to the satisfaction of the world that polar flying was not an impossibility. Fifteen years ago it was not possible to obtain a serviceable airship. But to provide an airplane with a range of five hundred miles could have been obtained with comparatively little expense. There was, of course, in those days, the question of engine reliability, but as mentioned before an explorer with airplanes forced to land would, if he landed safely, have an equal, if not a better opportunity of using his feet than he would if he had first struggled over the ice on the outward journey. Although it was fifteen years ago when I first planned an Arctic expedition by air, it was not until 1926 that I was able to do any flying in the Arctic regions. Eielson had been flying in Alaska during winter several years before and was, as a matter of fact, the first pilot to fly during winter in high latitudes in America. Our plans for 1926 called for two flights of five or six hundred miles into the unknown Arctic. We wish to go first north-west, then north-east of Barrow, and then, if our experiences made it seem possible, make a flight from Barrow to Spitsbergen. My interest was not principally the possible geographical discovery, but the possibility of locating a meteorological station somewhere in latitude eighty and between one hundred and eighty and one hundred and thirty-five West. This meteorological station was to be one of a chain I expect to see established in the future about the North Pole. My efforts in the Arctic for the last three years have been solely in the interests of a meteorological plan of international importance, but the meteorological plan is a subject for the attention of the Meteorological Society and in this address I will confine myself to the use of airplanes in the polar regions. There was much of the polar regions yet unexplored. If suitable sites are to be located for the meteorological stations, then airplanes can be used for that purpose both in the Arctic and Antarctic regions.

The machines chosen for our first year's work in the Arctic were Fokker monoplanes, selected for several reasons. It seemed to me that high-lift wooden-winged monoplanes would be of great advantage under Arctic conditions. In the first place they had proved their efficiency. The Fokker was the only three-engined machine then available. It was my private opinion that the multiple-engine machine loaded to its maximum capacity was not an additional factor of safety, but public opinion was such that it seemed to demand the use of a three-engined machine for hazardous ocean flights. The high-winged monoplane, giving maximum clearance and wide landing gear, would be an advantage if a forced landing had to be made in the Arctic pack. The Fokker machines were comparatively fast, a quality in my mind highly important for the work we had to do. Without meteorological information from outlying districts it would be necessary to wait for a favourable opportunity to hurry the job. So far as I knew the aerodynamic qualities the Fokker wing curve was

the most efficient available and would allow of the greatest loading per square foot commensurate with speed. Only one trimotored machine was available, it was the first seventy-two-foot winged Fokker machine ever made. Since that time a similar machine was used by Commander Byrd on his flight to the Pole and the same type of machine was used for his New York to Paris flight. The other machine available to us was a sixty-three-foot Fokker monoplane fitted with Liberty water-cooled engine. If we were to take advantage of the best weather conditions for Arctic exploration by air, we had, after the machines were available to our expedition, no time to test them in New York. Neither did it seem necessary to do so. Our final tests would have to be made at Fairbanks, Alaska, in temperatures far below zero and any flying done in the moisture-laden atmosphere about New York during winter would be of little value. Our machines reached Alaska on schedule time, but unfortunately due to slight errors of judgment on the part of the pilots, both machines were badly crashed on their initial flights. I was perhaps the only one connected with our expedition who realised what those crashes meant. They really meant that it would be impossible that season to have even a small chance of successfully carrying on our flights of exploration. By the time the machines were repaired and our gasoline forwarded to Barrow, the season for successful flights for Arctic exploration would be past. And so it proved. It was three weeks after the crash that the first machine was ready for work and six weeks before the three-engined machine—which was intended for use over the ice—was fit to take the air. Our chances for much work in 1926 were small, still on the first flight north we went out over the unknown Arctic pack for a hundred and fifty miles—about 200 miles from shore—before coming to Barrow for the first landing. This flight gave me additional assurance that a forced landing on the Arctic pack would not necessarily mean disaster. We saw many possible landing places. It was the only flight over the ice we made that year. But our experiences proved to those who needed proof that both water-cooled and air-cooled engines would function if properly cared for even in temperatures of fifty degrees below zero Fah. In the spring of 1926 we did over six thousand miles of flying within the Arctic circle; the lowest temperature experienced on the ground and in flight with the water-cooled engine was fifty-two below zero Fah. There was not the least difficulty experienced with the water-cooled engine, but we found that the propellers supplied and said to be suitable for work in warmer temperatures were not suitable for the Arctic regions. Because fog and clouds continually cover the Arctic Sea during late spring and summer we were forced to abandon our work for that year. The conditions we met had been just as my five years' previous polar experience had led me to expect. Our machines when well handled gave us no trouble except for the faulty propellers. Meanwhile Byrd had flown to the Pole and Amundsen, Ellsworth and Nobile had crossed from Spitsbergen to Alaska. The Pole had been reached by air. The public thought the work in the Arctic had been accomplished. It seemed to the uninformed that we had been badly beaten in the race, and that there was nothing left to do. They had forgotten that our work was not at all to reach the earth's geographical centre, but to explore the unknown area in the Arctic.

In 1906 it was assumed that Amundsen had proved that no large area of land existed directly between Barrow and the North Pole, and as our short flight of reconnaissance over the ice gave me the added assurance of finding landing fields in the pack, our plans were slightly changed. Instead of making non-stop flights to the north-west and north-east of Barrow, we would take lighter machines needing a shorter runway for a take-off and with sufficient range to enable us to fly our five hundred miles and, if land was not seen, take soundings and return to Barrow. The Stinson biplane built in Detroit, powered with Wright whirlwind motor, a machine that was new in design, but which had proved its efficiency, was selected. Two of these machines were taken to

Barrow, and using the supplies we had placed there the year before we commenced operations.

Knowing something of the meteorological conditions at Barrow during late March and early April, I planned to take advantage of a small storm approaching from the east, fly north-west with the wind, land, take a sounding; we would then fly south in a more or less calm belt and on the return trip take advantage again of the wind, which would, under ordinary circumstances, be, by the time we turned for our base, again in our favour. These plans might have carried well but for the fact that our engine gave trouble, mostly due I think to interference in the gasoline supply, but partly due to faulty ignition. We were first forced to land on the ice about fifteen minutes before I had planned to do so. A landing field was selected, and a landing was made on the Arctic pack about five hundred and sixty miles from shore. We sounded and discovered that the sea beneath us was five thousand four hundred metres deep. There was little chance of an island being found in that vicinity. We started back for Barrow fifteen minutes later; we were again forced to land and a safe landing was made. This time we cleared the gasoline system and thoroughly overhauled the ignition; in three hours we were ready to start. We had used so much gas that there was no chance to go south and take advantage of the wind. As we approached land we must fight against a strong wind on our beam and hope for the best. The wind proved our undoing. We were more than seven and a half hours trying to cover the distance we had made in five on the way out and our gasoline gave out when we were seventy miles from our base. We were forced down to the Arctic pack again and this time in the midst of a high wind and snow storm. On no other ocean in the world could three safe forced landings be made with a landplane. The third landing was made late at night. It was greatly due to Eielson's skill as a pilot that we escaped with our lives. In utter darkness on that third landing he kept the machine level and into the wind, but Providence had a hand in guiding our destiny. It was impossible for us to select a smooth landing field; we could not see beyond the windows of the cabin, yet we came easily to rest on a smooth patch of ice scarcely half an acre in area and surrounded by high ice ridges. It would have been difficult for the most expert pilot to have put a machine down in the position we found ourselves when the weather and the blizzard cleared. Out of gasoline, drifting on badly broken pack ice, unable to communicate with our base, we would have been in a difficult position had it not been for the training I had received from Stefansson during the Canadian Arctic Expedition. As it was, it was only a matter of time before we reached the shore and safety. Sorrowfully leaving our machine behind, we walked and crawled over the ice and in eighteen days reached a trading post on the Alaskan coast. By the time we were ready to set out with our second machine, the season had advanced too far to allow successful flights of exploration. We started on two occasions and flew for two hundred and fifty miles to the north-east over low fog and cloud, hoping to find clear weather further north, but the fog seemed interminable and we had to postpone our efforts until 1928. With our machines in 1927 we did in all more than 8,000 miles of Arctic flying. The sounding we had taken showed that there was little chance of finding land in the area north-west and within six hundred miles of Barrow. Amundsen had covered the area directly north; there remained the north-easterly sector.

We had used Fokker monoplanes and Stinson biplanes with a certain measure of success. With the information then on hand, our plan for 1928 demanded the use of still another type of plane. True, the Fokker planes we had used the first year would have served our purpose, but they were no longer available. I decided this year to reduce the staff, arrangements and expenditures to the minimum. I would select the fastest plane capable of carrying the necessary polar sledging gear, sounding apparatus and other scientific and

navigation equipment, two months' food supply, a radio outfit, the pilot and myself, and enough gasoline to cover a distance of two thousand seven hundred miles. We planned to fly north-east from Barrow, dumping part of our load and landing if we saw land or indication of land within the first six hundred miles. But if no indication of land was seen we proposed to keep on to Spitsbergen and fully complete the programme commenced in 1926.

The Lockheed Vega Monoplane built in Los Angeles seemed best to suit my purpose. A short technical description is attached. I saw the first one of its kind, it came to grief on the flight from San Francisco to Hawaii, but a cursory examination of that machine and a close study of the designers' figures and drawings assured me that the Lockheed was the plane for us to use. I placed an order for the second machine to be built and watched its construction. It was to be of the standard cabin design with just a few slight alterations for the convenience of Arctic navigation. These alterations would not affect the aerodynamic qualities of the machine. In detail they amounted to a different distribution of windows, an arrangement to give the maximum light in the navigator's cabin and facilitate his ability to take observations of the sun and drift and ground speed. An addition was made to the instrument board in front of the pilot. It held beside the ordinary tachometer thermometer, pressure gauge, altimeter airspeed indicator and watch, an additional altimeter, registering accurately to two feet, a turn and bank indicator, a fore and aft inclinometer, a lateral inclinometer, one fast-moving compass and one slow-moving compass. The navigator's equipment was an ordinary eight-inch boat compass, a prismatic surveyor's compass, a Royal Air Force bubble sextant, a pocket sextant, a Pioneer Instrument Company's drift indicator, a course and distance calculator, protractors (one arranged to serve as an azimuth circle), charts, log books, tables designed curves cut in celluloid, nautical almanac, etc., provided and arranged for by Mr. O. O. Miller, officer in charge of the School of Surveying, American Geographical Society. An explanation of this method is attached. In theory the correct navigation of a course between Barrow and Spitsbergen was complicated and its complications magnified by the fact that we planned to swing to the East and not follow a meridian of longitude north of the Pole and south to Spitsbergen. On the course we wished to follow we would cross through 171 degrees of longitude and through a difference of three hundred and fifteen degrees of compass declination, and in an area where horizontal forces influencing the compass were small and perpendicular forces strong and unknown. The course I plotted was a great circle course for the first thirteen hundred miles, then turning obliquely to the right on another great circle course for nine hundred miles, two thousand two hundred miles in all. I planned to make it in legs of a hundred miles, changing our course about every hour, depending of course on ground speed and the meteorological conditions encountered.

At first it appeared as if the complications would make the steering of a compass course an impossibility, but I found on carefully working out the track, applying the corrections required for declination and the frequent change of longitude, it would not be so difficult. The greatest alteration in our compass course would need to be between the ninth and twelfth hours of flight, but the greatest changes in any one hour would not be more than twenty-five degrees. The actual change of direction of flight, since our course would cross the top of the world, would be much more. There was also the question whether our compasses would work in the air in those longitudes. I myself was in doubt about this. Queries from Eielson during our flight brought the repeated reply: "One of my compasses swings all the time and the other stands steady at three thirty degrees." My compass in the cabin, free from all engine or other metal influence, was remarkably steady. Naturally it was not possible to check it with absolute precision. It never is possible in an airplane when flying through a variety of atmospheric conditions to mark with exact precision the reading of the compass

at any point of the journey. Every pilot will vary his course a few degrees to one side or the other and it is necessary for the navigator to be constantly on the watch, constantly recording and allowing for such movement. One acquires, with experience, ability in this matter which no amount of figuring can master. Now I come to the point mentioned at the beginning of this address, the facilities the Arctic conditions afford the aerial navigator. You must know that most, if not all, successful long distance flights depend in a measure on piloting—as piloting differs from navigating. By piloting I mean in this instance dead reckoning and taking advantage of ground observations. Dead reckoning depends on the accuracy of observations for ground speed and drift. Accurate corrections to offset the drift can only be had with a knowledge of time of travel and the height above the object observed. With regard to the latter, travelling over the Arctic Ocean affords the same facilities as travelling along a coast. There are always points on which to observe, and from the altimeter which registers only the height above sea level we know our exact height above the object observed. This simplifies the problem to a great extent.

There are many conspicuous points on the Arctic Sea ice which the pilot can use for a line-up and hold his machine steady while the navigator takes observations, but there is one warning I must announce, the pilot should only use these points during the periods of observation. He should, if possible, steer by his compass, otherwise if the pilot keeps his direction by observing objects ahead and allowing for the wind the navigator would be unable without constant watch on the drift indicator and a multitude of calculations to know the extent of the drift, and on a long great circle course where it is often necessary to fix positions and take so many points of departure it would surely lead to trouble. For short distance flying, however, these possibilities for ground observations are a great aid to the pilot. There are many other conditions which aid the man with experience to keep his course if the weather is clear during a journey over the Arctic ice—the direction of drifts on the ice, the movement of ice in the leads, the direction of the leads themselves and the effect of the ice pressure. We know from experience that the ice pack shows the influence of a wind far from the position of observation, and it is sometimes possible to forecast with accuracy from the observation of ice movement the wind that will be later experienced. For the navigator's aid in the Arctic spring and summer there is the sun constantly above the horizon. During spring it is generally visible at all times from the ground. During summer it is generally hidden except from an altitude of three or four thousand feet, but at that height it would be possible, on long-distance flights, to depend with more or less accuracy on sun observation for locating position. With a bubble sextant of the type made by the Pioneer Instrument Company, New York, or of the R.A.F. type used on our flight this year, it is possible if the air is smooth and if the pilot flies the ship steadily, to obtain comparatively accurate observations, and by using stereoscopic charts and the simplified methods arranged by Mr. O. O. Miller, of the American Geographical Society, a copy of which is attached, it would be possible to maintain a fairly accurate course. That my sun observations, dead reckoning, and compass control kept us within a few miles of the course we had planned was fortunate, but all the knowledge of navigation in the world would not serve were it not for the aid of a skilful pilot, a serviceable machine and a reliable engine. I was well favoured on the Arctic flight by having the reliable Wright Whirlwind, the perfect Lockheed Vega Monoplane and such a companion and pilot as I have found in Carl Ben Eielson.

Lockheed Vega Monoplane

Now, as regards the technical details of the "Vega." The wing section is a tapered "Clark Y" aerofoil; the tip being the standard, or 11.7 per cent. ordinate Clark Y section, while the thick centre section is the 18 per cent. thick modified Clark Y section. The taper is uniform between tip and centre. The

chord at the centre is 102 inches, the span 41 feet, the maximum thickness slightly more than 18 inches, and the total wing area 275 square feet (not deducting anything for fuselage interference). Ailerons are differentially operated and have an area of 12 square feet each.

The wing spars are of the conventional spruce box type, with spruce cap strips tapering in plan form and section in proportion to the load carried, from about $\frac{1}{2}$ inch square at the tips to almost 3 inches square in the centre. The spar webs are three-ply spruce, $\frac{1}{8}$ thick with grain at 45 degrees to the axis of the spar. The front spar tapers in depth from 17 inches at the centre to 5 inches at the tip, the rear spar is not quite so deep. Internal diaphragms are used to stiffen the webs on 6-inch centres near the centre of the spar and on 12-inch centres out towards the tip. Extra heavy blocking is provided at tank supports and wing hold down fittings.

Ribs are of conventional spruce truss type, cap strips being laminated to shape, while the truss members are spruce, attached to caps with $\frac{3}{32}$ spruce plywood gussets. Twenty ribs are used, spaced 2 feet on centres and connected laterally by light spruce girders which help to support the plywood between the ribs.

The wing is completely covered with $\frac{3}{32}$ spruce plywood assembled with casein glue. The plywood is attached with barbed brass nails and casein glue.

The fuselage is of a streamline form, 45 inches wide, 60 inches high and 27 feet 6 inches long, following closely the best streamline shapes developed at the Gottingen Laboratory. The fuselage shell is $\frac{5}{32}$ three-ply, vertical grain spruce, two outer layers running fore and aft, the central layer at 90 inches to the outer layers. The shell is nailed and glued to elliptical transverse spruce diaphragms, which vary in size and strength according to the loads to be carried. The shell is heavily reinforced around cutouts for wing, cockpit, windows, etc. Tail surfaces are of conventional section, with spruce I spars, spruce girder ribs and plywood covering.

Metals used are low carbon sheet steel and tube for welded fittings; heat treated chrome molybdenum alloy steel for axles, skid, control parts and engine mount; aluminium alloy (duralumin) for chassis struts, fittings, control stick, fireshield and fairings; aluminium for tanks and cowling; copper for fuel and oil lines.

Instructions for Utilising the Sun as a Means of Navigating in the Polar Regions

Explanation of Method

Provided the Greenwich apparent time of observation is known, then by observing an altitude of the sun it is possible to define one's position as being somewhere on a circle of equal altitude which has as its centre the point on the earth's surface at which the sun was in the zenith or directly overhead at the moment of observation. The radius of this circle is equal to the complement of the observed altitude, in other words, the zenith distance. When in the polar regions it is very easy, and requires no computation, to plot this position line on a chart, because the meridian which the sun was crossing at the time of the observation is known and the distance from the pole along this meridian to the point where the circle of equal altitude cuts it is equal to the difference between the sun's declination and the observed altitude. If the altitude is larger than the declination, this point is between the pole and the sun, but if the opposite is the case then the point lies on the opposite side of the pole to the sun, and the meridian on which it lies will be, obviously, 180° apart from the sun's meridian. The circle of equal altitude must cut the sun's meridian at right angles, and consequently if a curved ruler of the right radius is placed against this point on the chart so that its tangent is at right angles to the meridian,

the position line can be simply drawn across the sheet of paper. This is in effect what is actually done. As the sun is so near the equator and the observer's position so near to the pole, the radius of the circle of equal altitude will always be large. Also, curves of varying radii having a common tangent diverge slowly from one another. Consequently, it has been found sufficiently accurate for the purposes of plotting position lines in the polar regions to construct only ten curves of different radii on a sheet of celluloid. The particular curve most suitable for the occasion may be determined by the table attached, using the declination and the observed altitude as arguments. By choosing the right curve the greatest displacement of the true position line will be about 1.5 mm., and this only on the extreme edges of the chart when the sun's hour angle is about 6 hours.

The plotting of this position line will give an observer an independent check on the accuracy of his dead reckoning while flying, and when on the ground if the altitude of the sun is observed twice or more at the same position with intervals of three or four hours between observations, then more than one position line can be plotted, and where they intersect on the chart will be the position of observation.

When, by whatever means, the position of observation has been plotted on the chart, it is then possible to obtain direction from the sun. Now, in high latitudes the bearing or azimuth of the sun (measured from S. by W. in north latitudes, and from N. by W. in south latitudes) is very nearly the same as the sun's hour angle, (the hour angle is the difference in time or longitude between the observer's meridian and the meridian which the sun was crossing at the time of observation). Consequently, the most convenient way to determine true north in its relation to the sun is to first determine the sun's hour angle and to this apply a small quantity dependent on the latitude and declination. This quantity is the difference between the hour angle and the required azimuth and may be obtained from the tables attached.

The sun's hour angle is obtained in arc, provided the observer's meridian and the sun's meridian are indicated on the chart, by measuring clockwise from the former to the latter along the scale on the perimeter of the chart. Then when in northern latitiudes and when the sun is west/east of the meridian of observation, add to/subtract from the hour angle 180° and the quantity extracted from the tables. Again, when in southern latitudes, when the sun is east/west of the meridian of observation add to/subtract from the hour angle 180° and the quantity extracted from the tables. In both cases the result will be the sun's azimuth measured clockwise from the pole.

Discussion

The President said he was sure that all those present would like, before the discussion was opened, to welcome Lieutenant Eielson, who piloted the Vega monoplane across the Arctic. Lieutenant Eielson had been co-operating for some time with Sir Hubert Wilkins in the Arctic and there can be no doubt but that his special knowledge of flying under these extreme conditions contributed greatly to the wonderful success that had been achieved.

The lecture had shown that the Arctic was not that impenetrable region it was popularly supposed to be, nor did it cover the vast area which anyone might imagine to be the case when glancing at Mercator's projection. The flight which Sir Hubert Wilkins had described was so very remarkable that it was difficult to select outstanding features in their order of merit. One point of considerable interest was that, whilst most long flights had been undertaken between well organised bases, in this case the flight was started at one desolate spot, ending, if it were possible, in an even more desolate one. When the lecturer showed us a picture of Point Barrow, Alaska, and talked glibly of a village, he felt sure all would agree that nothing was to be seen which bore any similarity to a

village as we know it. The immense difficulties that must have presented themselves in organising the flight under the conditions met with were very evident, and the triumph was all the greater. The last 200 miles to Spitsbergen, through a blinding snowstorm accompanied by a high wind, were certainly terrible, and a successful landing in these conditions was truly a marvellous achievement.

Sir GILBERT WALKER (Professor of Meteorology at the Imperial College of Science) said that his first remark must necessarily be an expression of the profoundest admiration for the bravery and the enthusiasm for science which this work had exemplified. Meteorologists were continually finding that the alliance between their subject and aviation was becoming closer. Neither science could get on without the other, and as a meteorologist he was very proud to realise that the lecturer of the evening was quite as enthusiastic on his meteorology as on his aviation. He desired, therefore, to put one or two questions to him on subjects which were puzzling many students of meteorology, owing to their lack of information about conditions in the Arctic. One of these questions had relation to the extent to which depressions could penetrate the far north, say north of latitude eighty. Meteorologists were rather tempted to consider that north of that latitude strong winds were rarely to be encountered. Another question regarded the extent to which Sir George Wilkins was troubled with the formation of ice on his airplane. The speaker had the impression that in thick mist or cloud there was considerable likelihood of an accumulation of ice on the machine, but from the lecturer's remarks that evening he did not seem to have been greatly troubled in this respect. The last question was one of fundamental importance in meteorology, namely, the extent to which it was possible in the near future to start observatories in Arctic regions, where they would be of very great scientific value, apart from their obvious usefulness in throwing light on aeronautical conditions. The speaker felt confident that in twenty years' time it would be possible to convey the necessary stores to an observatory on the extreme north of Greenland, deposit observers there, and remove them after three or six months. But he desired to know whether Sir George Wilkins was of opinion that this was a practicable scheme in a nearer future.

Air Commodore LONGMORE said there were various problems on the equipment side on which he would like to ask a few questions. He noticed that Sir George Wilkins said that he was able to keep perfectly warm in temperatures even of 40 deg. below zero in an ordinary fur coat made by the Esquimaux. That seemed curious to those of them who in service machines at much higher temperatures than that required electrical heating. Presumably Sir George Wilkins had no electrical heating in his fur clothing. Again, he would like to ask about the actual provisions taken on the expedition, whether they were meat capsules or chocolate. Any small details of that sort would be very useful. Then he wished to know the actual type of gasoline used. Was it the plain gasoline or was ethyl used in it? Was any particular form of oil used? Again, his friends of the Technical Department might be tempted to ask what was the actual factor of safety of the aircraft when he took off at Point Barrow. These were only just a few questions which occurred to him on the spur of the moment.

Major CASEY (representing the High Commissioner for Australia) expressed the regret of the High Commissioner that he was unavoidably prevented from being present. Had the High Commissioner been able to come he would have told the audience how proud Australia was of Sir Hubert Wilkins, not only of what he had done during his last great flight, but of all the achievements which stood to his credit during the last fifteen or twenty years of his very active career.

Colonel RICHMOND said that the only question he desired to ask Sir Hubert Wilkins was whether he could give them any cheering information on the likelihood of the rescue of the speaker's friend, General Nobile. They had all been following the messages which had come through, but, of course, to anybody who

had not been over those regions it was very difficult to say how far the messages derived their hopeful tinge from the particular correspondent who sent them, and how far they represented a genuine chance of getting General Nobile and his men quickly back to safety. He would add only how much he admired the work which Sir Hubert Wilkins had done, though it was difficult to realise all that it meant, and how entirely he agreed with him that one day certain great circle routes would be across the Pole. He hoped within his own lifetime to see airships, and possibly airplanes, connecting up the places the lecturer had mentioned, by the great circle route across the North Pole.

Commander BRIGGS said that in such a story as the Society had heard that night the main importance would belong to the minute details, the ounces of this or that. Some very valuable information might be hoped for from such details of this experience, and he trusted that some such information would be forthcoming, if not that evening, at all events for some of the Society's future Proceedings.

Mr. COLLINS (Civil Aviation Department) said that Sir Hubert Wilkins had furnished many interesting details of various aspects of the flight, and he was only sorry that he had not gone on to give further details with regard to the navigational difficulties. Mr. Collins then asked the following series of questions:—

Map Projections.—In the advance proof he noticed that Sir Hubert had had a special map prepared for him by the American Geographical Survey. On what projection was that map based? Was it an existing map and, if so, would he not have preferred to have had a special map drawn for him either on the gnomonic or some sort of stereographic projection, which would simplify his navigation?

R.A.E. Sextant.—The speaker noticed that he had fixed his position once or twice by using the R.A.E. sextant. It would be interesting to know how he took his observations with that sextant from the air. Did he take just one sight or the mean of six sights? Further, how often did he take those sights? Was it after relying on his dead reckoning for a few hours, or did he take them every one or two hours? Were the errors due to refraction caused by the low altitude of the sun in that latitude of a sufficiently high order to be allowed for in the air?

Compasses.—Three compasses—one fast, one slow-moving, and some other particular type of compass were apparently used. He would like to know precisely what types of compasses they were, and why Sir Hubert chose a fast-moving as well as a slow-moving one. Also, was the slow-moving one similar to the British type of aperiodic compass? For example, did it possess a very light magnetic system, as that seemed to be an important point when a magnetic compass was being used in high latitudes, where the value of the earth's horizontal force was small? Where was the compass compensated before the flight and what were the coefficients?

Altimeter.—Sir Hubert Wilkins referred to an additional altimeter, registering accurately to two feet. The speaker was not aware of an instrument which had an accuracy of that order. Which type was used, and was any allowance made for horizontal variation of barometric pressure in the course of his flight?

Great Circle Courses.—He gathered that Sir Hubert steered two great circle courses, and he had said that he had to change his course no more than 25 deg. in every hour. That was an alarming enough change when one relied solely on one's confidence in one's own work. But could he safely go on one course for an hour and then change, or was he able to check the turning points either by drift observations or by astronomical finesse? It struck him as an extraordinarily fine piece of work, to keep one's dead reckoning so accurately when such large changes of course were necessary.

Mr. GRIFFITH BREWER congratulated Sir Hubert Wilkins on the remarkable flight he had made, which, as they all knew, was only an extension of a large period of exploration over the polar ice. He wished to congratulate him also on his presentation of his subject; he had known him for eight years and did not know that he could speak for an hour fluently without a note, in a way unexcelled by any lecturer in that room. He believed he was right in saying that his was the first flight from the Pacific Ocean to Europe with only one stop. They had to fly over from Fairbanks on the Pacific to Point Barrow on the Arctic, from which the second stage to Spitsbergen was flown. Finally, he wished to congratulate Lieutenant Eielson on being the first human being to make his first entry into Europe *via* Spitsbergen.

Mr. COLEBROOK: He had one serious question: What exactly could be gathered as to the arctic conditions from an aeroplane travelling approximately at one hundred miles an hour? It seemed rather difficult when one was practically in an enclosed compartment. By what means was exterior information of permanent value gathered when the aeroplane was only in one area for so short a space of time?

Major ROBERTSON desired to hear anything that Sir Hubert Wilkins could tell them about his Antarctic plans. He had told him something about them three years ago, and they were exceedingly interesting. Had he any plans for using the same type of machine or taking Lieutenant Eielson as pilot?

Mr. SCOTT HALL asked whether Sir Hubert Wilkins thought that the airplane was really a better vehicle for exploration in these regions than the airship. He had always understood that fog was very prevalent over the arctic ice. Was not the airship a better vehicle to use in the case of fog? What conditions did he expect to meet with in the Antarctic as compared with those in the Arctic, from the aeronautical point of view?

A SPEAKER asked for a little more information about navigation, particularly with regard to the weather. Was it possible to rely on magnetic compasses, or was the Goerz compass necessary, or could wireless beacons be used?

A SPEAKER asked whether the lecturer used his echo apparatus for sounding at all?

A SPEAKER asked for information as to the general direction of the wind in that region. Was it round the pole?

Sir SEFTON BRANCKER: During 1917 he had had the honour of having an Australian squadron in his command. His experience with this squadron led him to think that the Australians should make the finest airmen in the world. Soon afterwards, he was sent on a mission to America and quickly realised that that country also would produce magnificent airmen. That experience had been fully borne out by the many wonderful feats performed by Australian and American airmen since 1918. Sir Hubert Wilkins' flight was not a stunt, but an exploration of real practical value. It was not only useful as an effort to discover more about Polar weather conditions from which we suffered so much in this country. He was convinced that some time in the future we should see air routes established across the Polar regions. One of the great advantages offered by air transport was that it could take advantage of a short cut over the top of the world instead of having to slavishly follow the sea and the land, as other means of transport were forced to do.

He happened to be chairman of an international committee which had been appointed to consider the question of the charts which would be required in the future for air navigation in the Arctic. Up to date, this committee had decided to come to no decision! Sir Hubert Wilkins' lecture made him think that the committee must now wake up and seriously consider the problem, as a demand for such charts would soon arise. It was regrettable that Sir Hubert Wilkins could not have been backed by British capital and provided with British aircraft. However, perhaps it was just as well that he did not try to start on any of his

great flights from England; he had confessed that, although he was a pilot, he had never taken out a licence; and he had admitted in his lecture that, so far as airworthiness went, his machine was carrying 3,500 lbs. instead of the 2,000 lbs. authorised! Such behaviour would probably have got him into serious trouble with the civil aviation authorities!

Reply to Discussion

Captain Sir G. H. Wilkins, in replying on the discussion, said that he would try and answer the questions in the order asked. The first question was about the air conditions and the winds in the Polar regions. It had been his belief and his understanding from an examination of the records kept within the Arctic Circle that it was probably one of the calmest zones in the world. His flights did not take him anywhere near the North Pole itself, but high winds were found only near the great land masses. At his farthest distance from shore comparatively calm air was experienced, and north of Greenland he got into still air conditions. Therefore it seemed to him that if the actual area around the Pole itself were investigated, remarkably still conditions would be experienced. This followed, he thought, the general law of air movement. He had, of course, very little information of his own, because the information in relation to the winds which could be collected when one was travelling 120 miles an hour was not of very great importance.

While on this question, he might say something about the wind direction around the Pole. While there might be a number of circular storms formed—and he believed that around the edge of the Arctic was the common centre for the development of circular storms—there was no direct indication that the wind blew around the Poles. He was more inclined to believe that winds blew from the Poles southward or northward as the case might be, that the general trend was from the Poles towards the Equator. It was on that broad principle that it was worth while to establish stations as near the polar area as possible so as to get the general direction and force of the descending polar currents starting their motion towards the warmer regions. It was believed to be possible to learn very much about these matters from observation in these regions, but only after having stations in the Polar regions for fifteen or twenty years or longer was it likely that authentic information would be gained about the cycle of seasons which was now known to be a fact. That was the very reason why he took an airplane through Spitsbergen. In future, by establishing meteorological stations in those high altitudes, it might be possible to reap some advantage in relation to seasonal variation.

With regard to the formation of ice on the machine, he chose to go early in the year when the temperature was low, and he believed that in the low temperature there would not be the formation of ice. He had never had occasion to fly in the Arctic Circle when the temperature was high, and it had never been his experience to get more ice on the machine than just a small collection around the gasoline pipes, and that only during the first year of the expedition. The trouble was avoided later by protecting the gasoline pipes by means of asbestos or some similar material. He had learned from General Nobile that the Italian aviator had had considerable trouble from ice forming on the machine during his flight across the Pole. The speaker was well aware that ice would form and adhere to the wooden wings of the machine, because at times when it had been at rest on the ground the melting snow had frozen again and an accumulation of ice was discovered, which, however, was easily removed. But in flying 18,000 miles within the Arctic Circle he had had no trouble from ice on the airplane.

The question had been asked whether it might be possible to establish meteorological stations in these outlying districts. He believed it would be

economically possible to maintain these stations by airships, and in Berlin there was now a society actively engaged on a programme for carrying out that work. He believed that this society would have at its disposal a German Zeppelin, which would leave its hangar early next month (July), and that it was intended to maintain many stations in the Arctic. The speaker believed that it was possible to-day to establish such stations in the Antarctic and maintain them for part of the year with the help of boats. It was his plan to have at least twelve stations maintained in the Antarctic—four apportioned to Africa, four to Australia, and four to South America. The respective bases would be Cape Town, Melbourne and Buenos Aires. He believed that the twelve stations could be maintained, provisioning them in summer, and using the boats to collect biological and other information on the outskirts. It was also expected to get the distribution of the ice, not just by one observation from a boat, but daily, or weekly at least, and this would give some idea of the effect of ice distribution on the ocean temperature and its ultimate effect on the weather conditions in those producing countries, Australia, South Africa and the Argentine.

One member asked about the temperature and body comfort in a thin fur suit at 52 deg. below zero. The speaker had had some experience with electrically-heated clothing just after the war, and he had found such clothing most cumbersome and awkward to use and not at all comfortable in its heating arrangements. He had learned as far back as 1913 how to be warm and comfortable in suits of fur clothing, weighing not more than nine pounds. The first suits used in the Arctic weighed between seven and nine pounds, and gave absolute comfort in temperatures ranging from 55 deg. below zero to 70 deg. Fahr. One precaution necessary to observe with fur suits was to refrain from wearing anything else underneath. The fur suit was worn next the skin. If one attempted to feel civilised with silk or linen underwear one was going to be uncomfortable. But if one's dignity could be maintained in a single suit, with no other clothing whatever, certainly comfort and warmth were secured.

As for provisions, it was found possible to buy some pemmican, biscuits and chocolate that had been specially prepared for Amundsen's expedition in 1920. This food was used in 1926, 1927 and 1928, and was found quite excellent. His load at the start was 120 lbs., and he and his companion Eielson consumed less than 15 ozs. of solid food each per day and felt quite fit. They had chocolate and biscuits and drank cold water. They used less than 2 lbs. of gasoline for melting the ice, and drank the water so obtained. The food problem was therefore not a serious one—a store of pemmican, chocolate and biscuits, and a small primus stove proved quite satisfactory. It had been the custom of other explorers to take coffee and all sorts of things, which were of course agreeable, but not essential.

The gasoline which was used in three years was presented to them by the Richfield Oil Company of California. It was perhaps a little better than some others, but he would not say that it excelled all other kinds of gasoline. They were, however, very well served in this respect, and they owed to the Richfield Company a very great debt of gratitude. Not only did that company provide them with 7,000 gallons of gasoline, but presented them with 12,000 dollars towards the expenses of the expedition. For the oil a preparation not specially thin was used; it was thick oil such as he would use in latitude thirty or thirty-five or in any other part of the world. A good quality Pennsylvania oil was found to serve their purpose very well.

A question had been asked as to the chance of rescuing General Nobile and his crew. It seemed to him quite possible that they would be brought back alive, but they would necessarily suffer a great deal of hardship and discomfort, because just now was the worst season of the year to be exposed in the Arctic. This was the between-seasons, when it would not be possible for them to lie down without soon being surrounded by a pool of water. They must be having

a perfectly wretched time, but knowing General Nobile as he did, and being aware of his great ability, he believed that he was capable of meeting extreme conditions, and that the people under his command would be as well cared for as possible. The speaker was looking forward every day to the news that an airplane had been near enough to them to drop down provisions and comforts. Within a few weeks it would be possible for an ice-breaker to reach somewhere in their vicinity, and they would be rescued. What had happened to the others who had been carried away with the airship there was nothing on which to base a conclusion.

With regard to the maps, a friend of his—an Englishman, he was proud to say, but now employed by the American Geographical Society—really worked out his navigation problems. It was decided to prepare a special map for the purpose on a stereographic projection. The size of the map was 15 in. square, a convenient size to use in an airplane. The information as to the simple method of navigation was taken by Mr. O. O. Miller from a paper by Mr. A. R. Hinks, of the Royal Geographical Society. From this a simplified method was worked out, and one which was easy to apply even in a fast-moving airplane. With the Royal Air Force sextant this year he preferred to take six sights of the sun for every position. He took many positions, perhaps ten or twelve throughout the flight, and at many other times he would take a sight of the sun and work it out roughly, but there was great trouble with refraction at midnight. At midnight the sun was about 4 deg. above the horizon, but he could see with the naked eye the influence of refraction on the sun, and it was never possible to get a reading within 2 deg. of what he had taken just before. Between three in the morning and nine at night, however, the trouble from refraction was not very great. The time for taking sights was not decided on any particular hard and fast rule. He planned to take sights as often as he conveniently could.

It was asked what might be observed from an airplane travelling at such speed. It was only his previous experience with Stefansson that enabled him to make any useful observation. Such observation would not be possible for any man without previous experience. But after travelling over the ice on foot, watching snow drifts forming, hiding behind the wind, and finding one's way only by means of the direction of the snow and wind, one accumulated experience which was of assistance in interpreting the conditions while flying. It was possible for him to see through the windows of his cabin the direction of the snowdrifts and the movements of the ice, and he could tell from what direction the wind was moving when a pressure ridge was formed. But this was possible only through the training he had received with Stefansson. There were so many little details that it would be impossible to say exactly how these Arctic conditions were interpreted.

The compasses used this year were a Pioneer ordinary pilot's compass and a star compass, quite a new instrument, but the compass on which he relied in his navigation was the ordinary ship's compass, and was intermediate between fast and slow. He did not pay very much attention to the provision of compasses this year. He believed when they set out this year that they could not reap much advantage from compasses. He expected to have to depend on piloting, keeping his direction by observation of the ice and snowdrifts, and fixing his position from time to time by the sun. But almost at every point when he could fix his compass, he was very much surprised to find that had they been compelled to fly the whole course depending on the compass it might have been possible.

Some question had been raised about the number of courses on the journey. He planned, when he set out, to change the course every hundred miles. This meant changing course twenty-two times on the route. Someone had asked about sun compasses. He used the sun compass for two years and found when flying on a north-south course that it was very useful indeed, but it did not act

very well on a cross longitudinal course, and as it was necessary to cross 170 deg. of longitude on this flight he did not bother to take the sun compass with him.

There was some talk of fog over the Arctic being a difficulty. It was certainly a difficulty if one wanted to see what was beneath. But fog over the Arctic rarely reached a height of 4,000 feet. The Arctic, he thought, did offer many facilities for navigating and piloting and flying that were not to be found in any other part of the world. The question of sounding was one which was solved by the Germans with a small portable echo-sounding device, and it was with that portable device that he was able to take the sounding last year. This year he carried also a manual sounding apparatus, using an ordinary cinematograph reel and some specially made silk fishing thread for the line. But there was no occasion or opportunity to use it this year and it had been returned in the machines to America.

Somebody had asked him about his Antarctic plans. He had discussed these thoroughly three years ago and had not altered them. He expected to use a machine of somewhat similar design to the one used this year. He would prefer to use a British machine and to set out with British capital, for the work was in an area essentially British; but he found that in this country there was not such a clear understanding of the scientific value of the work as in other countries, and that was in a way regrettable. For several years he had attempted in Australia—and for a short period in England—to interest people in carrying out this work, but with very little success so far as advances of money were concerned, and when he was invited to America he was conscious of the great honour bestowed on him by the American people in the interests of meteorology and science in general. Science was international. It had been a great privilege to carry out this work, which, he might add, was not of particular interest to America, but of general interest to all.

Lieutenant EIELSON added a few words in which he said that the greatest consideration of all was the engine. There were manufacturing and other problems in connection with the engine for use in these temperatures which had still to be solved. To have some way of adjusting the engine to the temperature was the main consideration in the operation of air traffic in the Far North.

SOME NOTES ON TEMPERATURE GRADIENTS IN IRAQ

BY FLIGHT LIEUTENANT E. J. D. TOWNESEND, B.A., A.F.R.AE.S.

1. Whilst carrying out various tests on radiators and airscrews in Iraq, it was necessary to take the air temperatures up to 10,000 feet, and the results of twenty-six flights are given in these notes as it is thought they may be of interest to aircraft designers requiring data to predict the performance of their aircraft in a tropical climate.

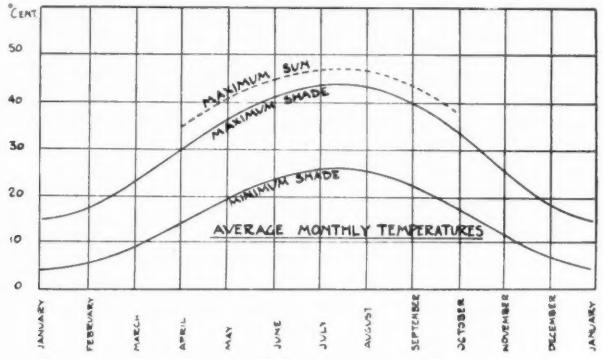

FIG 1

2. As a general indication of the climatic conditions in Iraq, Fig. 1 shows the average ground shade temperatures for each month over a period from 1922 to 1926, as recorded at Hinaidi, an R.A.F. aerodrome about six miles from Baghdad. The sun temperature has been taken as about 40°F. (4.5°C.) higher than the shade temperature. These shade temperatures were taken at 05.00 hours G.M.T., or about 08.00 hours local time.

3. The twenty-six gradients are tabulated in the Appendix together with the standard height according to the S.T.Ae. law. The height was obtained from a standard R.A.F. altimeter locked to read zero feet at 29.9 inches of mercury and calibrated in a vacuum chamber. No corrections were made for temperature effects. The temperatures were read from a strut thermometer and the tests were carried out on D.H.9A or Bristol Fighter aircraft.

4. The graphs shown in Figs. 2 to 4 show the average temperature gradient at about 06.30, 08.30 and 10.30 hours local time during the summer months. They are the average of various flights and show the very marked temperature inversion up to about 2,000 feet in the early morning and its gradual disappearance during the morning. It reappears in the same marked manner in the evening. The dotted lines are the boundaries of the actual gradients when plotted individually. The S.T.Ae. law gradient on the left is shown for comparative purposes, and it will be observed that the lapse rate is slightly greater in Iraq. In general, the pressure at ground level is low.

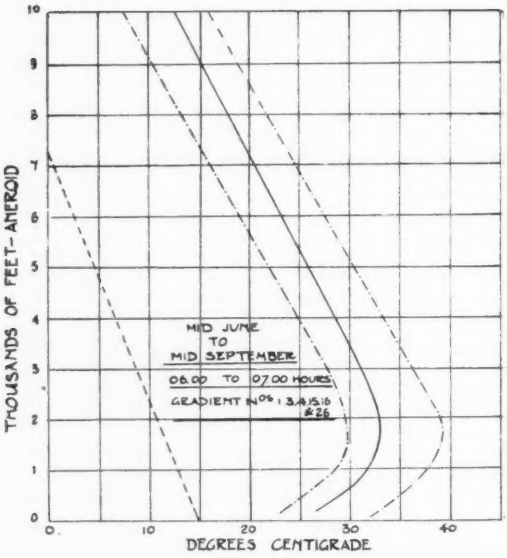
THOUSANDS OF FEET-ANEROID
DEGREES CENTIGRADE
MID JUNE
TO
MID SEPTEMBER
08.00 TO 07.00 HOURS
GRADIENT Nos 1 3 4 5 6 1 & 26

FIG 2

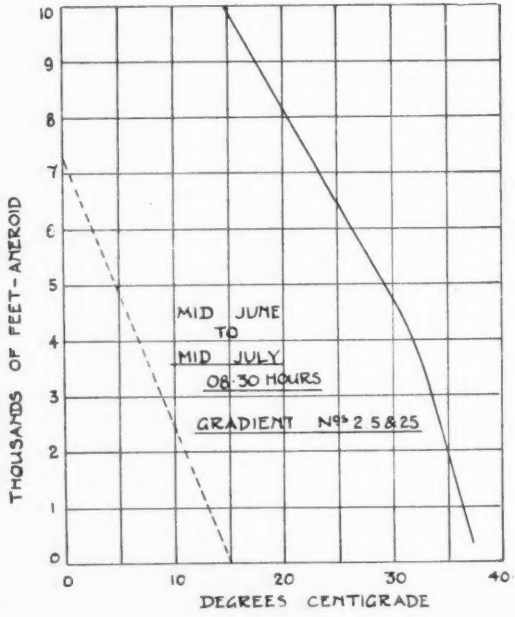
THOUSANDS OF FEET-ANEROID
DEGREES CENTIGRADE
MID JUNE
TO
MID JULY
08.30 HOURS
GRADIENT Nos 2 5 & 25

FIG 3

5. During the winter months the gradients are comparable with English summer conditions. Figs. 5 and 6 indicate this. Temperature inversions are still found as late as 11.00 hours, the gradients in Tables Nos 20 and 23 of the Appendix show this in a marked manner. The ground pressure is, in general, high.

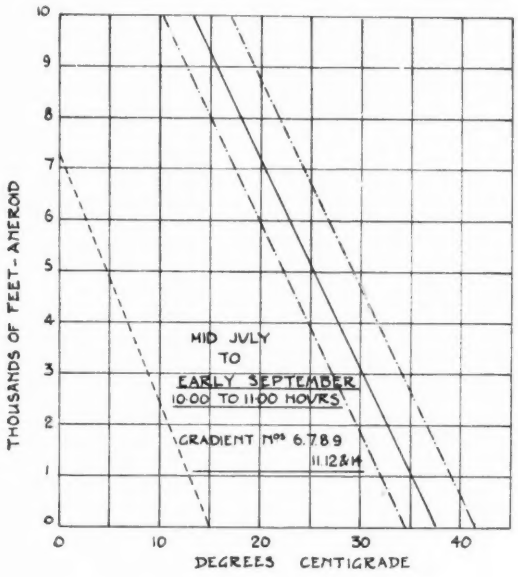

FIG. 4.

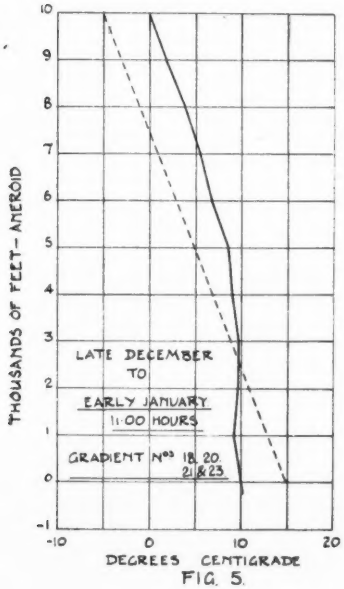

FIG. 5.

6. When considering air densities during the summer months for aircraft performance predictions, greater ground temperatures that 50°C. may be disregarded and a lapse rate of about 2.1°C. per thousand feet can be assumed. During the winter months the temperature range varies from the English summer to the winter temperatures of snow clad mountains. Even Baghdad has snow and ice.

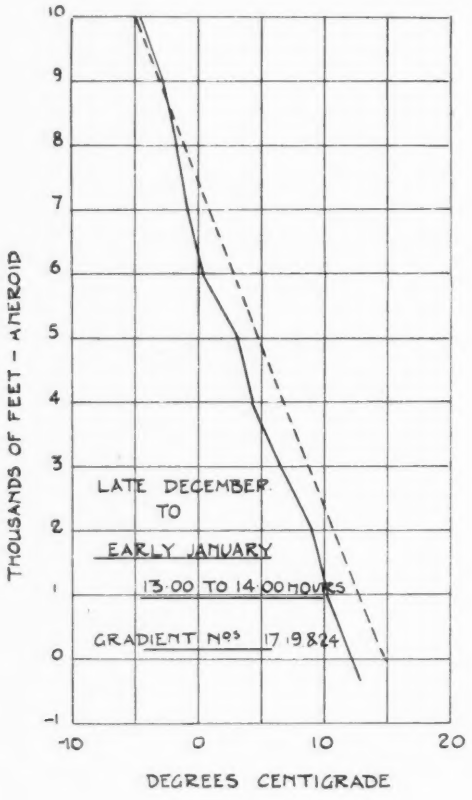

FIG. 6

7. The decrease of air density in summer, and the increased all-up weight and head resistance due to tropical and desert equipment required on aircraft designed for a temperate climate and operated in a tropical country, is very evident in the performance of the aircraft.

8. The effect of the heat and light is very marked on rubber and where it must be used as a shock-absorbing device it is better to use it in compression than in tension, but wherever possible it should be discarded. The design of the undercarriage and tail skid is of even greater importance than in a temperate climate, as changing a wheel in the desert due to a burst or punctured tyre is an uncomfortable operation, especially if the lifting jack sinks into the ground. On single-engined aircraft the airscrew should be sufficiently accessible to use as one method of starting the engine.

9. For aircraft having water-cooled engines installed, the radiator problem is one requiring considerable thought. Where the temperature varies from extreme cold to tropical heat a detachable radiator is necessary, and yet the extra weight and possibly head resistance has to be added at a time of year when it is most disadvantageous. In addition, the supply of water that must be used may be such that the difficulties of corrosion and sediment have to be faced to a greater extent than in a temperate climate.

APPENDIX

TABLE OF TEMPERATURE GRADIENTS.

GRADIENT No. 1.

24/6/1926—06.10 hours.

Height in Feet.	Temperature °C.	Standard Height.
+190	25	1,420
1,050	31	3,100
2,000	32	4,400
3,000	31	5,550
4,000	28	6,450
5,000	25.5	7,350
6,000	23	8,240
7,000	20	9,120
8,000	17.5	10,000
9,000	16.5	11,000
10,100	14	12,030

GRADIENT No. 2.

26/6/1926—08.20 hours.

Height in Feet.	Temperature °C.	Standard Height.
+180	39	2,950
1,050	38	3,960
2,000	35.5	4,280
3,000	33	5,750
4,000	31.5	6,775
5,000	29	7,725
6,000	26	8,580
7,000	24.5	9,525
8,000	21	10,340
9,000	18.5	11,260
10,100	16	12,125

GRADIENT No. 3.

29/6/1926—06.00 hours.

Height in Feet.	Temperature °C.	Standard Height.
+190	28.5	1,800
1,050	33	3,380
2,000	35.5	4,775
3,000	33.5	5,775
4,000	31.5	6,225
5,000	28.5	7,625
6,000	25.5	8,530
7,000	23	9,425
8,000	20	10,325
9,000	17.5	11,150
10,100	15	12,080

GRADIENT No. 4.

8/7/1926—06.25 hours.

Height in Feet.	Temperature °C.	Standard Height.
+190	27	1,980
950	29	2,800
1,950	29.5	4,630
2,950	27.5	5,100
3,950	25.5	6,100
4,950	22.5	6,950
5,925	20	7,875
6,900	16.5	8,950
7,900	14	9,475
8,850	11	10,250
9,850	8.5	11,125

GRADIENT No. 5.

15/7/1926—08.40 hours.

Height in Feet.	Temperature °C.	Standard Height.
+435	33·5	2,675
950	32	3·130
1,950	31	4,250
2,950	32	5,560
3,950	31	6,630
4,950	28	7,500
5,925	25	8,375
6,900	22	9,200
7,900	19·5	10,050
8,850	16	10,775
9,850	13	11,650

GRADIENT No. 6.

22/7/1926—10.05 hours.

Height in Feet.	Temperature °C.	Standard Height.
+150	39·5	2,975
1,000	38·5	3,350
2,050	37	5,025
3,050	34	5,900
4,075	31	6,800
5,000	28	7,580
6,000	25	8,500
7,000	22	9,325
7,975	19	10,125
8,950	16	10,900
9,900	13·5	11,750

GRADIENT No. 7.

27/7/1926—10.10 hours.

Height in Feet.	Temperature °C.	Standard Height.
+385	37	2,980
1,000	35·5	3,550
2,050	33	4,600
3,050	32	5,700
4,075	30	6,700
5,000	27·5	7,500
6,000	24·5	8,440
7,000	22	9,325
7,975	19·5	10,175
8,950	17·5	11,075
9,900	17	12,125

GRADIENT No. 8.

13/8/1926—10.10 hours.

Height in Feet.	Temperature °C.	Standard Height.
+260	36·5	2,775
1,000	34·5	3,450
2,050	32	4,480
3,050	29	5,400
4,050	27	6,325
5,000	24·5	7,180
6,000	22·5	8,175
7,000	20·5	9,150
7,950	18	10,000
8,900	15	10,730
9,850	12	11,525

GRADIENT No. 9.

16/8/1926—10.20 hours.

Height in Feet.	Temperature °C.	Standard Height.
+220	36	2,675
1,000	34·5	3,450
2,050	31·5	4,425
3,050	29	5,400
4,050	26	6,250
5,000	24	7,150
6,000	21·5	8,075
7,000	18·5	8,900
7,950	15·5	9,700
8,950	17	11,050
9,850	15	11,850

GRADIENT No. 10.

17/8/1926—12.50 hours.

Height in Feet.	Temperature °C.	Standard Height.
+255	38·5	2,980
1,000	38	3,350
2,050	34	4,725
3,050	32	5,675
4,050	28	6,450
5,000	24·5	7,200
6,000	21	8,025
7,000	19	8,975
7,950	19·5	10,125
8,950	17	11,025
9,850	15	11,850

GRADIENT No. 11.

30/8/1926—10.20 hours.

Height in Feet.	Temperature °C.	Standard Height.
+170	36.5	2,660
1,000	34	3,380
2,050	31	4,375
3,050	28	5,290
4,050	25.5	6,180
5,000	23	7,075
6,000	20	7,915
7,000	18.5	8,915
7,950	18	10,000
8,950	16.5	10,975
9,850	14.5	11,925

GRADIENT No. 12.

1/9/1926—10.30 hours.

Height in Feet.	Temperature °C.	Standard Height.
+240	35	2,575
1,000	32.5	3,260
2,050	30	4,270
3,050	28	5,280
4,050	26	6,250
5,000	24	7,150
6,000	21	8,025
7,000	18.5	8,910
7,950	16	9,800
8,950	13.5	10,700
9,850	11.5	11,650

GRADIENT No. 13.

3/9/1926—11.20 hours.

Height in Feet.	Temperature °C.	Standard Height.
+190	37	2,750
1,000	35	3,500
2,050	32	4,500
3,050	29	5,400
4,050	27	6,350
5,000	24	7,150
6,000	21.5	8,075
7,000	18.5	8,900
7,950	16	9,725
8,950	14	10,725
9,850	10.5	11,350

GRADIENT No. 14.

9/9/1926—10.55 hours.

Height in Feet.	Temperature °C.	Standard Height.
+75	39.5	2,850
1,000	37	3,725
2,000	34.5	4,680
2,900	32	5,475
4,000	29	6,500
4,950	26.5	7,350
5,950	24.5	8,350
6,950	21.5	9,175
7,900	19	10,050
8,800	15.5	10,675
9,750	11.5	11,350

GRADIENT No. 15.

14/9/1926—06.25 hours.

Height in Feet.	Temperature °C.	Standard Height.
−50	25	1,110
1,000	30.5	3,040
2,000	31	4,340
2,900	29	5,210
4,000	27	6,300
4,950	24	7,100
5,950	22	8,075
6,950	19	8,925
7,900	17	9,825
8,800	14	10,540
9,750	12	11,400

GRADIENT No. 16.

17/9/1926—06.35 hours.

Height in Feet.	Temperature °C.	Standard Height.
+150	22	1,730
1,000	31	3,100
2,000	32	4,425
2,900	30	5,325
4,000	28.5	6,425
4,950	26	7,300
5,950	23.5	8,230
6,950	21	9,150
7,900	18	9,925
8,800	15.5	10,700
9,750	13	11,540

GRADIENT No. 17.

28/12/1926—13.30 hours.

Height in Feet.	Temperature °C.	Standard Height.
−200	14	−330
1,000	10	+675
2,090	10	2,025
3,000	7	2,800
4,000	5	3,775
5,000	3	4,975
6,020	0	5,675
7,000	−2	6,580
8,000	−3	7,675
9,000	−5	8,600
10,000	−6.5	9,575

GRADIENT No. 18.

31/12/1926—11.00 hours.

Height in Feet.	Temperature °C.	Standard Height.
−390	8.5	−1,225
1,000	7	+300
2,000	6	1,450
3,000	6	2,675
4,000	5	3,775
5,000	4.5	4,970
6,000	3	6,025
7,000	2.5	7,100
8,000	1.5	8,175
9,000	0	9,175
9,950	−1	10,175

GRADIENT No. 19.

4/1/1927—14.00 hours.

Height in Feet.	Temperature °C.	Standard Height.
−340	10	−980
1,000	8	+450
2,000	6	1,450
3,000	5	2,575
4,000	4	3,675
5,000	3	4,800
6,000	3	6,025
7,000	1.5	6,975
8,000	0	8,000
9,000	−1	9,075
9,950	−4	9,820

GRADIENT No. 20.

5/1/1927—11.00 hours.

Height in Feet.	Temperature °C.	Standard Height.
−270	9.5	−950
1,000	9	+575
2,000	11	2,050
3,000	12.5	3,450
4,000	12.5	4,680
5,000	12	5,850
6,000	10.5	6,870
7,000	9	7,875
8,000	6	8,700
9,000	4	9,670
9,950	2	10,525

GRADIENT No. 21.

7/1/1927—10.40 hours.

Height in Feet.	Temperature °C.	Standard Height.
−245	12	−625
1,000	10.5	+725
2,000	9	1,800
3,000	9	3,050
4,000	8.5	4,225
5,000	8	5,400
6,000	6	6,350
7,000	4.5	7,350
8,000	3.5	8,430
9,000	2	9,400
9,950	0	10,325

GRADIENT No. 22.

8/1/1927—09.30 hours.

Height in Feet.	Temperature °C.	Standard Height.
−150	9	−850
1,000	10.5	+725
2,000	12	2,150
3,000	10.5	3,225
4,000	10	4,400
5,000	9.5	5,560
6,000	9	6,700
7,000	6.5	7,575
8,000	4.5	8,525
9,000	0.5	9,240
9,950	−1.5	10,110

GRADIENT No. 23.

8/1/1927—11.00 hours.

Height in Feet.	Temperature °C.	Standard Height.
−150	10.5	−680
1,000	10.5	+725
2,000	12.5	2,200
3,000	11	3,257
4,000	10	4,375
5,000	10	5,620
6,000	8	6,585
7,000	6	7,500
8,000	4.5	8,525
9,000	1.5	9,350
9,950	−1	10,225

GRADIENT No. 24.

10/1/1927—13.00 hours.

Height in Feet.	Temperature °C.	Standard Height.
−245	14.5	−350
1,000	13	1,025
2,000	11	2,025
3,000	7.5	2,875
4,000	4	3,675
5,000	4	4,900
6,000	−2	5,400
7,000	−2	6,600
8,000	−2	7,775
9,000	−2	8,950
9,950	−3	9,940

GRADIENT No. 25.

17/6/1927—08.30 hours.

Height in Feet.	Temperature °C.	Standard Height.
+300	39.5	3,150
1,000	39	3,975
2,000	38	5,025
3,000	35.5	6,025
4,000	32	6,825
5,000	29	7,675
6,000	25	8,780
7,000	24	9,480
8,000	21	10,340
8,950	18	11,150
9,950	15.5	12,000

GRADIENT No. 26.

28/6/1927—07.10 hours.

Height in Feet.	Temperature °C.	Standard Height.
+300	32.5	2,400
1,000	37	3,725
2,000	38	5,050
3,000	35.5	5,980
4,000	33	6,925
5,000	30	7,750
6,000	27	8,625
7,000	24	9,500
8,000	21	10,330
8,950	18	11,125
9,950	15	11,930

REVIEW

Elements of Aviation

Virginius Evans Clark. (Ronald Press Company, 1928. $3.00.)

Colonel Clark is one of the best known personalities in the United States of America. He graduated from the U.S. Naval Academy in 1907 and qualified as an aeroplane pilot in 1913. A fully qualified engineer, he became the Chief Aeronautical Engineer to the American Army and was appointed a member of the National Advisory Committee for Aeronautics. During the Great War he came to Europe to study what had been done and to advise the American Government what aircraft to build. In 1920 he became Chief Engineer for Aeronautics of the General Motors Corporation, and in 1922-23 Vice-President of the Society of Automotive Engineers.

Colonel Clark is widely known in this country, as in other countries, for his aerofoils, and many have been in use, notably on Colonel Lindbergh's "Spirit of St. Louis," the Douglas machines used in the round the world flight and the training and pursuit planes of the American Army and Navy; and the Arctic flight by Sir Hubert Wilkins.

With such a record one expects a sound book from Colonel Clark and one is not disappointed. The volume is intended to serve as an introduction to more advanced works on aeronautical engineering. In this the author succeeds admirably. The book begins with the usual (and in this case lucid) explanation of the forces on a flat plate and an aerofoil in a wind. The student must be clear, however, in reading the book to remember that Colonel Clark makes use of lift and drag coefficients which are confusing. With this proviso the whole of the book devoted to aerofoils is well written and the subject clearly explained. An excellent chapter is devoted to stability and control, explained without the use of long mathematical equations which so terrify the budding engineer. By means of simple everyday analogies Colonel Clark drives his points home in a way which can be understood without constant use of terms which are only used by the initiated.

The book ends with a series of definitions and a series of questions set upon the text. Answers to the latter might very usefully have been given so that the student could have had a check upon his results. The illustrations are simple and clearly drawn. *Elements of Aviation* can be recommended to all those who are sufficiently interested in flying to want to learn the principles of flight. As a book for beginners it is worth possessing and reading frequently.